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Junior Manual: Elect. Engin. Dept.

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JUNIOR MANUAL

ELECTRICAL ENGINEERING DEPARTMENT.

UNIVERSITY OF ILLINOIS.

Prepared by

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UNIVERSITY OF ILLINOIS.

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Department of Electrical Engineering.
University of Illinois.

PLAN OF THE WORK.

This Junior Manual has been prepared to serve as an outline and a guide for the students taking the Electrical Engineering Laboratory Course 21, at the University of Illinois. The experimental work covered by this course will be found outlined on page 11.

As far as practicable it is developed in the order indicated: The elementary work is taken by all the students. Selections are made from the more advanced ^eexercises to meet the requirements arising with the different classes of students.

The experimental work in the laboratory is co-ordinated as far as possible with the lectures and the text-book studies of the Electrical Engineering Course 1.

Actual practice by the student is regularly preceded or supplemented by illustrated lectures and experimental demonstrations bearing upon the subject in hand. The work of the student is not necessarily limited to the schedule, but is extended, as may be directed, while modifications of these experiments will suggest themselves. Every student has an opportunity several times in the course to have responsible charge of work, as the respective classes are divided into sections, of about six members each, with a different member in charge each day.

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Department of Electrical Engineering.
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COURSE OF INSTRUCTION IN ELECTRICAL ENGINEERING LABORATORY.

Course 21.- For students in other courses of engineering.

Electrical measurements of direct and alternating currents.

Double current generators; study, operating and performance.

Direct current dynamos and motors:

Study, inspection, operation and performance.

Direct current dynamos:

External characteristics and compounding.

Direct current dynamos:

Coupling in series, parallel and 3-wire systems.

Alternating current machinery:

Operation and performance of transformers, dynamos, synchronous and induction motors, synchronous converters.

Alternators:

Parallel working, synchronizing, single and polyphase.

Power measurements and efficiency tests:

Dynamos, motors, transformers.

Electrical transmission and distribution:

Inspection, management and testing of circuits and systems.

Photometry:

Inspection of electric lamps and elements of photometric measurements.

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JUNIOR MANUAL OF INSTRUCTIONS, FORMS AND SCHEDULES.

TABLE OF CONTENTS.	No. Pages.	Plate Reference.
 I.-INSTRUCTIONS.		
Instructions for Sections, -----	0.51	1,2
Section Leaders' Report,-----	0.52	3
Instructions for Use of Note Books,-----	0.54	4,5
Instructions for Reduction of Observations, ---	0.55A	6,7
Instructions for Use of Voltmeters, Ammeters, --	0.61	3
Instructions for Use of Indicating Wattmeters,----	0.62	9
Instructions for Use of Integrating Wattmeters, 0.63	10	3,30
		3,30
 II. FORMS.		
Forms, Requirements of Work and Report,-----	A,B	11
Form, Performance of Electrical Machinery -----	C	12
Form, Stray Power and Efficiency,-----	G	13,14
 III.- PRELIMINARY SCHEDULES.		
Inspection of Machinery and Appliances,-----	0.2	15,16
Operation of Elect. Mach. and Appliances,-----	0.4	17

Department of Electrical Engineering.
University of Illinois.

TABLE OF CONTENTS.

	No.	Pages.	Plate Reference.
IV.- GENERAL and DIRECT CURRENT WORK.			
Measurement of Armature Resistances, -----	1	18	4
Operation of Dynamos and Motors, -----	2	19	4
Operation of Dynamos and Motors, -----	4	20, 21, 22	6, 9, 10
Electrical Characteristics of Dynamos, -----	6	23	17
Coupling Direct Current Dynamos, -----	7	24	18, 19, 20
Compounding Machines, -----	8	25	
Motor-Generator Test, -----	11	26	26
Circuit Work, -----	61	27, 28	54, 56

Department of Electrical Engineering.
University of Illinois.

TABLE OF CONTENTS.

	No.	Pages.	Plate Reference
V.- ALTERNATING CURRENT WORK.			
Measurement of Inductances,-----	201	29	31
Determination of Angle of Lag,-----	203	30	31-33
Power and Power Factor of Alternating Currents,-204	31	31	30
Measurement of Capacity,-----	205	32	32
Inductance or Capacity in Series and in Parallel,206	33	33	34
Inductance and Capacity, in Series and in Parallel,207	34	34	35
Transformer Operation,-----	210	35	36,37
Transformer Testing,-----	211	36	38
Coupling Alternators, Synchronizing,-----	214	37,38	42,43
Synchronous Motor Working,-----	215A	39	45
Induction Motor Working,-----	218A	40	46-48
Rotary Converter Working,-----220A	41	41	
VI.- ELECTRIC LIGHTING.			
Incandescent Lighting,-----		42	
Arc Lighting,-----		43	
Inspection, Selection and Testing Incandescent Lamps,-----	320	44	51,53
Table of Contents.			
(v)			

MANUAL FOR ELECTRICAL ENGINEERING LABORATORY.

The Index number will be found on each blue print plate.

The Lantern Slide number corresponds to the same or similar view in the collection of the Department of Electrical Engineering.

Plates.

INDEX OF PLATES.

Slides.

1. Symbols and Conventions used in Wiring Diagrams.
2. Symbols and Abbreviations, adopted by the Paris Congress, 1900.
3. Diagrams of connections for laboratory instruments: voltmeters, ammeters, and wattmeters.
4. Methods of measuring resistances:
 - 1.-Fall of potential method for low resistances.
 - 11.-Comparative methods and insulation resistance.
6. Series Arc-lighting machines,-Brush and Thomson-Houston.-----613.
Armature connections and regulating mechanisms.
9. Starting Rheostat for shunt Motors, with automatic release and over-load circuit-breaker, connections.
10. Ward-Leonard system of Motor control:
Connections and characteristics of performance.-----614.
12. Magnetization(induction) curves: generators and motors.-----17.
Fleming's Rule, applied to dynamos and motors. -----80.
17. External Characteristics:
Shunt, series and compound dynamos and alternator.
18. Coupling direct-current dynamos and motors: series, parallel.- 616.
- 19,20Equalizing compound dynamos: diagrams and explanations.
21. Formulae for efficiencies of dynamos and motors. -----595.
25. Separation of losses and Efficiency
for compound dynamo.-----24.
26. Motor-generator Tests: Diagram of connections.
Efficiency by Hopkinson's and Kapp's methods.-----617.
27. Electric Transmission: illustration and example, in detail,
of direct-current transmission,-----90.
28. Electric Transmission: efficiencies from engine input to
motor output, power distribution and losses.-----618.
29. Electric Transmission: efficiencies of direct and alternating
current motors, and of shafting transmission-----619.
Index of Plates. (vi

INDEX OF PLATES.

Plates.

Slides.

30. Alternating Currents: Power Measurements, by wattmeters:
Two-phase and three-phase circuits.
31. Alternating current relations: circuits containing self-
inductance; lagging currents.----- 181.
32. Alternating current relations:
circuits containing capacity; leading currents,----- 182.
33. Alternating current relations: circuits containing
combined self-inductance and capacity, in series,----- 183.
34. Alternating current relations: circuits containing
inductance or capacity, in series and in parallel,----- 410.
35. Alternating current relations: circuits containing
inductance and capacity, in series and in parallel,----- 411.
36. Transformer connections, correct and incorrect; coupling,----- 186.
38. Testing Transformers: diagram of connections:
Double voltage, heating, Sumpner's method, regulation
copper loss and iron (core) loss tests.
42. ~~43~~ Coupling alternators: synchronizing, single and polyphase. 143
45. Synchronous Motors: phase characteristics, no-displacement curve.
46. Induction Motor: starting compensator and switch for
W.E. & M. machine, diagrams and positions. 185-
47. Induction Motor: Wagner machine, diagrams for various
operating conditions ----- 362.
48. Induction Motor: performance of 4 H.P. Wagner machine, --
Efficiency, power factor, torque, slip, watts, current,
51. Photometry: characteristics and distribution of light from
incandescent and arc lamps.
53. Photometry: characteristics of commercial incandescent lamps
under various conditions; good and bad results, target diagrams
57. Electrical distribution: various methods of feeding
two-wire incandescent lighting service, ----- 503.
58. Electrical distribution: three-wire (Edison) system,
evolution and modifications, ----- 506.
59. Electrical distribution: parallel and three-wire systems for
direct and alternating currents, ----- 34.
60. Four-pole machine: parts and details of, ----- 27
Index of Plates. (viii)

INDEX OF PLATES.

Plates.

Slides.

61. Windings of direct-current dynamos and motors, ----- 29, 40.
62. Four pole machine windings: combinations of, for various
uses as dynamo; shunt series, compound, ----- 60.
63. Commutation and armature reactions: magnetic fields of armature
and generator field, alone and in combination; brush
positions for dynamos and motors, ----- 420.
64. Alternating-current generator: two- and three-phase types,
with revolving armature and revolving field, ----- 427, 428
65. Inductor alternator: ideal magnetic circuits of, ----- 359.
75. Magnetization or saturation (B - H) curves for iron and steel. 69, 151.
79. Magnetic fields: of conductor, single loop, simple coil,
solenoid and dynamo, ----- 79.
82. Lines of force and equi-potential lines, for two similar
poles, two dissimilar poles, two conductors with currents
in same and in opposite direction, ----- 82.
103. E.M.F. curves: generated sine curves and rectified curves
for one-, two- and three- coil armatures, representing
elementary one, two, and three-phase dynamos, ----- 103.
120. E.M.F. curves: generated sine curves, curve of sine values
squared; distribution of potential around commutator
of direct-current machine, ----- 120.
125. Alternating current transmission: three-phase, and direct-
current distribution from rotary converters, 3-wire system, 500.
126. Electric transmission: development of Niagara diagrams of transmission,
distribution and utilization, ----- 126
180. E.M.F. curves: ideal and real curves, relations of E.M.F.
to curve of flux distribution, ----- 180.
361. Alternating current potential (or pressure) regulators; Kapp,
Stillwell, and Westinghouse stage *in production* ----- 361.
609. Electric traction: diagrams and combinations for series,
parallel operation of two-motor equipment of cars, ----- 609
612. Electric traction: three-phase transmission and direct
current distribution from rotary converters, ----- 612.

Index of Plates.

(viii).

PRINCIPLES OF DYNAMO-ELECTRIC MACHINERY.

I. ELEMENTS OF DYNAMO-ELECTRIC MACHINERY.

Generation of electromotive force. Establishment of electrical pressure.

- (1) By moving conductor in uniform field, cutting lines of force.
 - (a) A rectilinear conductor.
 - (b) A closed loop or coil of wire.
 - (c) A closed coil (as Gramme ring armature) or open coil (as Brush armature) in the field of a dynamo.
- (2) By moving a conductor in variable field, cutting lines of force. An open or closed coil as in an armature.
- (3) By varying flux distribution through a fixed coil, as in the Bell Telephone or an inductor alternator.

Laws: General laws of induction, - Faraday, Maxwell, Lenz.

Direction of movement of conductor, loop, or coil to generate Emf. Direction and magnitude of Emf. Fleming's rule.

II. -PRODUCTION OF MAGNETIC FIELDS. Fields around conductors.

- (1) A linear conductor: magnetic whirls around conductor.
 - (a) A single conductor.
 - (b) Two conductors, -currents in same or opposite directions.
- (2) A single coil or loop; polarity in normal plane, as armature.
- (3) A solenoid: linear, circular (as in solenoid ammeter coil).
- (4) An anchor ring, solid and cut.
- (5) A Gramme ring armature, -its field and polarity.
- (6) A simple dynamo: bipolar and multipolar frame.

Direction of current and polarity of field of force.

Ampere's rule, Maxwell's cork-screw rule, Fleming's rule.

III. -CHARACTER OF MAGNETIC FIELDS AROUND CONDUCTORS.

- (1) Distribution of magnetic fields, lines of force, polarity, &c.
- (2) Compare with similar distribution about magnets.
- (3) Lines of force and equi-potential lines.
- (4) Behavior of solenoids, similar to bar-magnets.
- (5) Exploration of magnetic fields of armatures and of generator field coils.

Syllabus of lectures. Principles of dynamo-electric machinery.

IV. - STRENGTHS IN "MAGNETIC FIELDS."

(1) Due to eddy or Foucault currents.

- (a) In copper disk, through air gap of magnetic circuit; as in Faraday's dynamo, or aluminium disk of wattmeter.
- (b) In copper cylinder, continuous, or split as in rotor of an induction motor of squirrel cage type.
- (c) In iron armature and transformer cores and pole pieces. Lamination, in direction of flux and transverse to conductor, reduces eddy current losses.
- (2) Repulsion experiments; of Ferraris, Fleming, Thomson.
- (3) Tractive or portative power; solenoid; lifting magnets.
- (4) Torque of armature in excited field of machine.
- (5) Short-circuited coil in armature.
- (6) Armature reactions and distortion of fields.

V. - INTERACTIONS OF "MAGNETIC FIELDS. INDUCTION EXPERIMENTS. INTERACTIONS OF FIELDS AROUND OR PRODUCED BY CONDUCTORS."

A. - Moving conductors in constant or uniform field (as direct current).

- (1) Two loops or coils; same plane, as in Hughes' experiment (induction) and the principle of Kelvin balance.
- (2) Two solenoids acting as bar magnets; linear approach.
- (3) Loops or coils, at an angle, as in Siemen's electro-dynamometer.

B. - Moving conductors and variable fields (as alternating currents). Induction Motor.

C. - Fixed conductors in variable fields of force.

- (1) Self-induction, in portions of same circuit.
 - (2) Mutual induction, between different circuits.
 - (3) Transformers.
 - (4) Induction alternators.
 - (5) Alternating current transmission lines.
- Laws and units of self-induction and mutual induction.

VI. - EFFECT OF IRON IN THE MAGNETIC FIELDS OF CONDUCTORS,

- (1) Compare two solenoids, with and without iron cores. Tractive and attractive forces.
- (2) Compare induction experiments, with and without iron.
- (3) Relations between B , H , and H .
- (4) Magnetic reluctance.
- (5) Hysteresis and hysteresis losses.
- (6) Magnetic circuits of dynamo-electric machines.
- (7) Electro-magnets and electro-magnetic mechanisms.

VII. - ELECTRICAL AND MAGNETIC CIRCUITS.

Units defined and laws of distribution.

Laws of Ohm, Joule, and Kirchhoff.

Simple, branched circuits and networks.

Syllabus of Lectures. Principles of Dynamo-electric machinery.

(x).

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INSTRUCTIONS for Sections in Electrical Engineering Laboratory.

Memoranda: (1) The Class will be divided into sections of about 6 members each, arranged alphabetically.

(2) Section Leaders will follow each other in the same order of rotation.

(3) All other members of the section follow each other in same alphabetical order, for assigned duties, as follows:

One Recorder.
Two Switchboard Attendants.
Two Dynamo Tenders.

General Instructions for all Members of Sections:

(1) Obtain copies of all Schedules and Forms, note details of same, and assignments, as posted for given day.

(2) Become familiar with all features of schedule.

(3) Study all references to Laboratory Manuals, etc.

(4) Each member is to hand in report on all the work, done by his section, according to assigned Form.

Instructions for SECTION LEADERS:

(1) Become familiar with the apparatus to be used.

(2) Prepare wiring diagrams of all connections required.

(3) Preliminary run: Ascertain best operating conditions.

(4) Determine upon and assign observation points.

(5) Give signal when observations are to be taken.

(6) Leave everything cleaned up, ready for next Section.

(7) Hand in Section Leader's Report, before leaving.

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INSTRUCTIONS for Sections in Electrical Engineering Laboratory.

Instructions for RECORDERS: See Instructions for use of Electrical Engineering Laboratory Note Books.

- (1) Prepare schedule of headings for tabulation of readings.
- (2) Make wiring diagrams of connections, as used.
- (3) Keep the log: record readings and note conditions.
- (4) Dictate the log to other members of section, at the close.

Instructions for SWITCHBOARD ATTENDANTS: See Instructions for the use of Instruments.

- (1) Obtain all instruments of proper capacity.
- (2) Connect instruments to external circuits, ready for use.
- (3) Take all readings, from these instruments.
- (4) Operate controlling and power-absorbing devices.
- (5) Stand by for any emergencies.
- (6) Disconnect, clean and return instruments.

Instructions for DYNAMO TENDERS: See Instructions for Operation, - Schedule 0.4; and Arts. A, B, C, of Schedule 4.

- (1) Attend to all work about apparatus used.
- (2) Get everything ready for operation.
- (3) Connect all wiring to and from their apparatus.
- (4) Obtain measuring instruments for use at apparatus.
- (5) Take all readings of instruments at apparatus.
- (6) Secure satisfactory operation during experiment.
- (7) Clean up, and leave in satisfactory working order.

University of Illinois. L. Schedule 0.62.

Section Leader's Report to be handed in, properly filled out, immediately after completing the work of the day.

No. of Experiment -----

Date -----

Apparatus used -----

Condition of apparatus when work was completed ----

INSTRUMENTS used (give name and Laboratory Catalogue No.) ----

Condition of Instrument when put away. -----

OUTLINE of work accomplished -----

Combinations, made as per schedule -----

Special combinations or work -----

DIFFICULTIES encountered -----

PRECAUTIONS observed -----

POSSIBLE Sources of Errors ----

A.M. Course No.----

Signed -----

Class--

Section-----3

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INSTRUCTIONS FOR USE OF NOTE BOOKS.

Every student will provide himself with two standard Electrical Engineering Laboratory Note Books. Each book has ten sets of sheets like the sample set bound in at end of this manual. These note books will be used each week alternately for report and examination. Always bring the Manual and Note Book to Laboratory.

Perform all work in the order prescribed in assigned schedule.

Note conditions under which each experiment is performed.

Note what is variable and what is kept constant.

Note time and character of any special features or changes.

Readings should be taken at regular intervals, by watch or signal.

Where any sudden change is expected, take more frequent readings.

Fill in Legend, top of first sheet, for each set.

Original Observations.- Record on first two sheets.

Laboratory Deductions. Approximate results are to be calculated or plotted, immediately after the performance of each experiment, in order: (a) to detect possible variations in the continuity of the work; (b) to check errors which may require a repetition of the work, in whole or in part. Approximate results and the log or record of original observations form the basis of the final report.

Description of the work. On third sheet. Be brief and to point.

State the object and purpose of experiment.

Describe the apparatus employed and how it was used.

Describe the methods pursued and state reasons for such methods.

State precautions observed, difficulties encountered, and how overcome.

State the principles illustrated or applied in the experiment.

Give the formulae and illustrate calculation, involved.

Interpret the data and the results of given experiment.

Account for phenomena observed by tracing cause and effect, in each.

State final results and draw correct conclusions from

Inst. Sheet : 0.54 (1) Use of Note Books

4.

INSTRUCTIONS FOR USE OF NOTE BOOKS.

Sketches and Diagrams. Draw only on the fourth (unruled) sheet, with neat and firm lines, self-explanatory sketches and diagrams using the conventions and symbols shown on Plate I. Sample calculations and use of formulae may also be put on this sheet.

Tabulation of Results. Tabulate, in ink, on the fifth sheet, so much of the original observed data as may be necessary to make, with the deduction therefrom, a complete and final table of results of the experiments.

Plotting Curves. Use only the last sheet of standard squared paper of each set of report sheets.

Select suitable scales to bring out characteristic features.

Scales should be easily read and interpolated.

(a) Pencil work. Plot points, as observed, in pencil.

To indicate points on different curves use small circles, of different sizes (o O): or other open figures (Δ $\square$) but not (x) marks.

Use only standard hard rubber curves in drawing.

Draw a fair curve by approximate method, where necessary.

Do not try to cover every point, by straight or curved line.

Begin curve at initial or zero point of observation.

End the curve at final observation point, not beyond.

(b) Inking in. Use only India ink.

Draw a fair curve, between circles of other designations of points of observation; do not draw across these points.

Axes and border to be drawn in with firm black lines.

Legend to be placed in lower right hand corner, filled in the same as that at top of first observation sheet; with name and number of experiment, date and name of student; and, a line below, stating what condition, or factor was maintained constant; such as speed, in determination of machine characteristics.

Final Reports, to be completed according to form specified, - A, B, C, etc., and to be handed in for examination, within one week of performance of the work.

Inst. Sheet 0.54 (2). Use of Note Books.

INSTRUCTIONS FOR REDUCTION OF OBSERVATIONS.

References:— Carpenter, R. C.; Experimental Engineering, pp. 1-15.

Merriman, M.; The Method of Least Squares.

Holman, S. W.; Discussion of Precision of Measurements.

E. W. G. R., 27:57 Jan. 11, '96. "Errors in Testing".

"An experimental result whose reliability is unknown is nearly worthless. The grade of accuracy of a measurement must be adapted to the purpose for which the result is desired. The necessary accuracy must be secured with the least possible expenditure of labor,.. and hence with judicious distribution of effort among the various parts of the work". — Holman.

Classification of Errors:

(1) Systematic or constant errors, which effect the same quantities in the same way: (a) instrumental errors, detected by calibration or special methods of adjustment; (b) personal errors, due to the observer's habit and methods and ascertained by comparison of observations.

(2) Accidental errors, whose presence cannot be foreseen nor prevented, but if many observations are made the occurrence of these errors can be predicted by the law of probability, and the probable value of these errors computed by Method of Least Squares

Elimination of Errors:

From the results of a series of observations on a presumably constant quantity, all taken under the same conditions, determine the value of the systematic errors and eliminate them. The remaining errors, which cannot be accounted for by imperfections of instruments or peculiar habits of the observer may then be subjected to the method of least squares for determining their probable value.

Axioms relating to the Probability of Errors.

(1) Small errors will be more frequent than large ones.

(2) Errors of excess and deficiency (that is, results greater or less than the true value) are equally probable and will be equally numerous.

(3) Large errors, beyond a certain magnitude do not occur. That is, the probability of a very large error is zero.

Errors of Simple Observations.

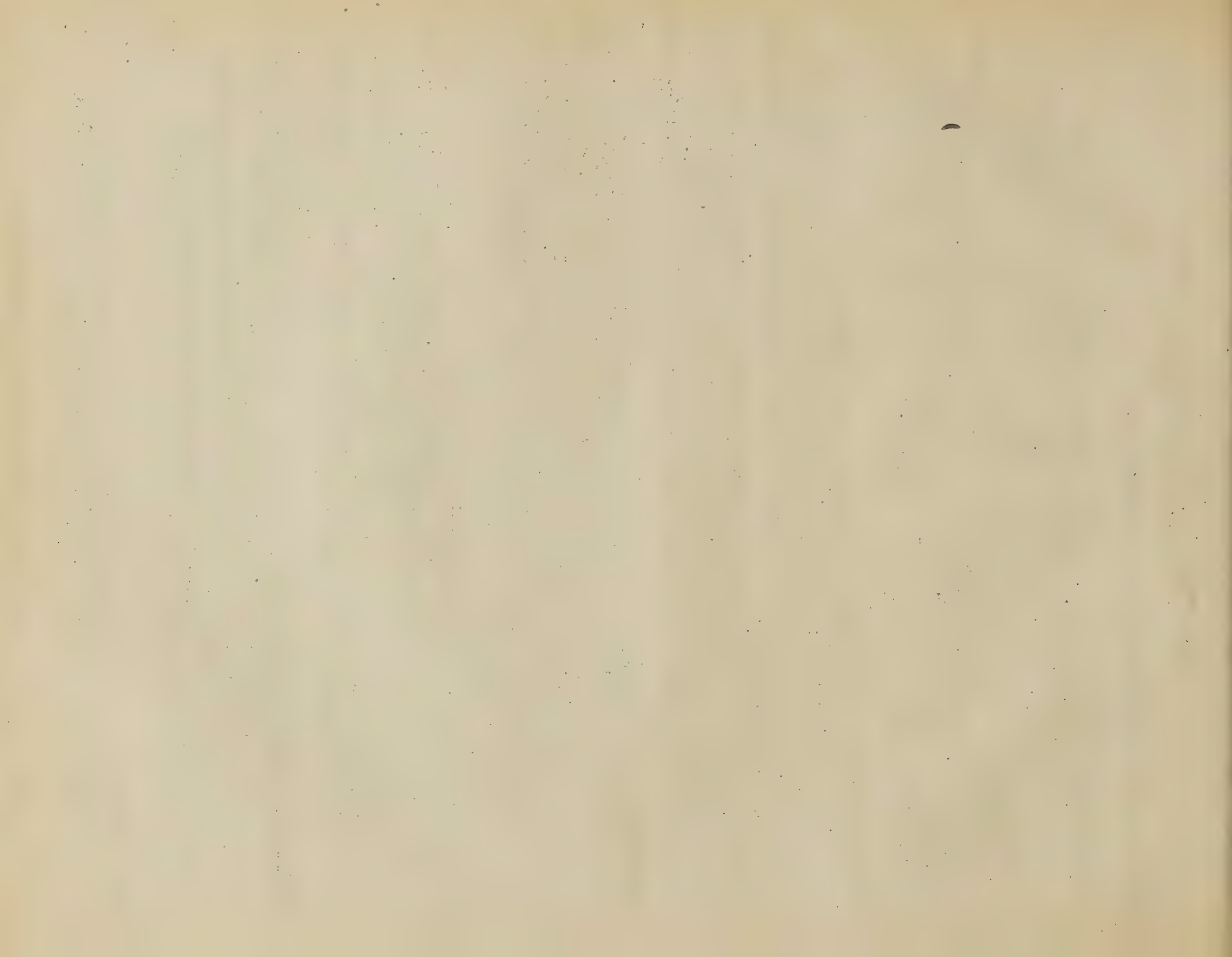
(1) The most probable value of a series of observations made on the same quantity is the arithmetical mean.

(2) If the observations were infinite in number the mean value would be the true value.

The residual is the difference between any observation and the mean of all of the observations.

Check Methods:

To obtain most accurate results and get clue to constant errors, independent results should be obtained by as many different methods as possible; and the several results compared.



METHOD OF LEAST SQUARES.

Let (n) equal the number of observations.

(s) equal the number of the squares of the residuals.

Then: Mean error of a single observation: $\pm \sqrt{\frac{s}{n-1}}$ (1)

Probable error of a single observation: $\pm 0.6745 \sqrt{\frac{s}{n-1}}$ (2)

Mean error of the result: $\pm \sqrt{\frac{s}{n-1}}$ (3)

Probable error of the result: $\pm 0.6745 \sqrt{\frac{s}{n(n-1)}}$ (4)

Rejection of Doubtful Observations:

- (1) If a mistake has occurred and cannot be corrected with certainty, the observations should be rejected.
- (2) After making allowances for all constant errors, no results except those which are unquestionably mistakes should be rejected.
- (3) The remaining discrepancies will then fall under the head of irregular or accidental errors.

Kinds of Measurements:

- (1) Direct measurements, made by methods and instruments whose indications give directly the quantity sought.
- (2) Indirect measurements, in which the quantity determined is not given directly by measurements taken, but must be calculated from them.
- (a) In this case all of the quantities measured are subject to correction; but it is necessary to correct by abstruse, difficult or lengthened calculations, for influences which make less difference than the least possible unit to be determined by observation.
- (b) The accuracy of the result depends not on the number of decimal places in the result, but on the least errors made in the observations themselves.
- (c) The result is to be carried out to one more place than the errors of observation would indicate as accurate: the last decimal place should make no pretensions to accuracy; the one preceding should be quite accurate.
- (d) Errors of method may be inherent, results failing to be correct however accurate the components may be, as in stray power method, in which it is assured that the stray power is the same, empty or loaded, certain conditions being fulfilled.

Mean Errors:

The mean error is the arithmetical mean (average) of the differences between the mean (average) result and the single observations.

If the systematic or constant errors have varied during the experiment, the observations and each partial result should be separately corrected before calculating the mean.

The relative mean error serves as a basis for discussing tests:

$$\text{Relative mean error} = \frac{\text{mean error}}{\text{result.}}$$

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INSTRUCTION SHEET.- Use of Portable Voltmeters.

- 1.- Handling. Avoid all shocks and jarring actions.
- 2.- Setting up. Place on firm and level support, at least six feet away from masses of iron, the machine fields or heavy currents.
- 3.- Connecting. Use flexible cord, as furnished for this purpose. On double scale instruments, connect terminals for higher scale, first, and take precautionary reading. Plus to plus.
- 4.- Voltmeter key to be released at once, on reading.
- 5.- Voltmeter Multipliers always to be connected in series with the instrument. Note, carefully, multiplying factor.
- 6.- Short circuits on voltmeters must be absolutely avoided.
- 7.- Low-reading Voltmeters must not be connected to circuits with voltages beyond the limits of their scale readings.

INSTRUCTION SHEET.

Use of Portable Ammeters.

- 1.- Handling. Same care as in voltmeters.
- 2.- Setting up. Same care as in voltmeters.
- 3.- Connecting. Same, as in voltmeters.
- 4.- Series ammeters may be left in circuit.
- 5.- Shunt ammeters, must be connected up only for reading. Ammeter shunts to be in series with the circuit, and ammeter in shunt with the same, by connections provided for the purpose.
- 6.- Machines must not be short circuited through an ammeter.
- 7.- Use ammeters on circuits only within scale readings.

NOTE:-

- 1.- Obtain and return instruments through Storekeeper.
- 2.- Avoid wiping Glass over instrument before reading.
- 3.- Read all mirror instruments, normally.
- 4.- Never remove instrument covers. Report faults and return.
- 5.- Return instrument clean and in good condition.

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INSTRUCTION SHEET. - Use of Indicating Wattmeters.

- 1.- Readings of indicating wattmeters are in true watts or kilowatts, regardless of power factor of circuit.
- 2.- Handling.- Avoid all shocks and jarring actions.
- 3.- Setting up.- Place on a firm and level support at least six feet away from machine fields or heavy currents.
- 4.- Connecting.- See Sheet of "Diagrams of Connections for Laboratory Instruments". Connect current coils with special connectors furnished with the instrument. Connect pressure coil with flexible cord.
- 5.- Current coils are to be connected in series in one side of the circuit.
- 6.- Pressure coils are connected across circuit.
- 7.- On double scale instruments, connect pressure terminals to higher scale first, and take precautionary reading.
- 8.- Release key at once after taking every reading.
- 9.- Multipliers are to be connected in series with pressure coil and in position shown on Diagram, NEGLECT OF THIS WILL BURN OUT INSTRUMENT.
Note carefully, multiplying factor.
- 10.- Use instruments only in circuits within scale readings.
- 11.- Injury from large initial currents must be guarded against, as when starting induction motors under load, by temporarily short circuiting the terminals of the current coils till normal or steady conditions are assured.

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University of Illinois.

INSTRUCTION SHEET.- Use of Integrating Wattmeters.

- 1.- Readings of integrating wattmeters are in true watt-hours or kilowatt-hours regardless of power factor.
- 2.- Handling. Avoid all shocks and jarring actions.
- 3.- Setting up. Suspend or place in a perfectly level position, away from active fields or heavy currents.
- 4.- Connecting. - See Sheet of "Diagrams of Connections of Laboratory Instruments". Connect main terminals in series in one side of circuit. Connect potential terminal across to other side of circuit.
- 5.- If no constant is given the instrument reads directly in watt-hours. If constant is given, multiply by it to reduce to watt-hours.
- 6.- If case is opened be very careful that no dirt gets on commutator or rotary disk.
- 7.- When properly connected meter disk will always rotate in direction indicated by arrow on disk or other revolving part.
- 8.- Use instruments only in circuits within specified limits as noted on name plate.

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Form A.

Requirements of Laboratory Work and Report.

Write a Report on the assigned work, as performed under the several items of the Given Schedule, referring to the same, by the designated numbers or letters, and treat in the following order:

1. Object of the work, in brief.
2. Methods of conducting the work, and reasons for the same.
3. Sketch diagrams of electric circuits and of connections used.

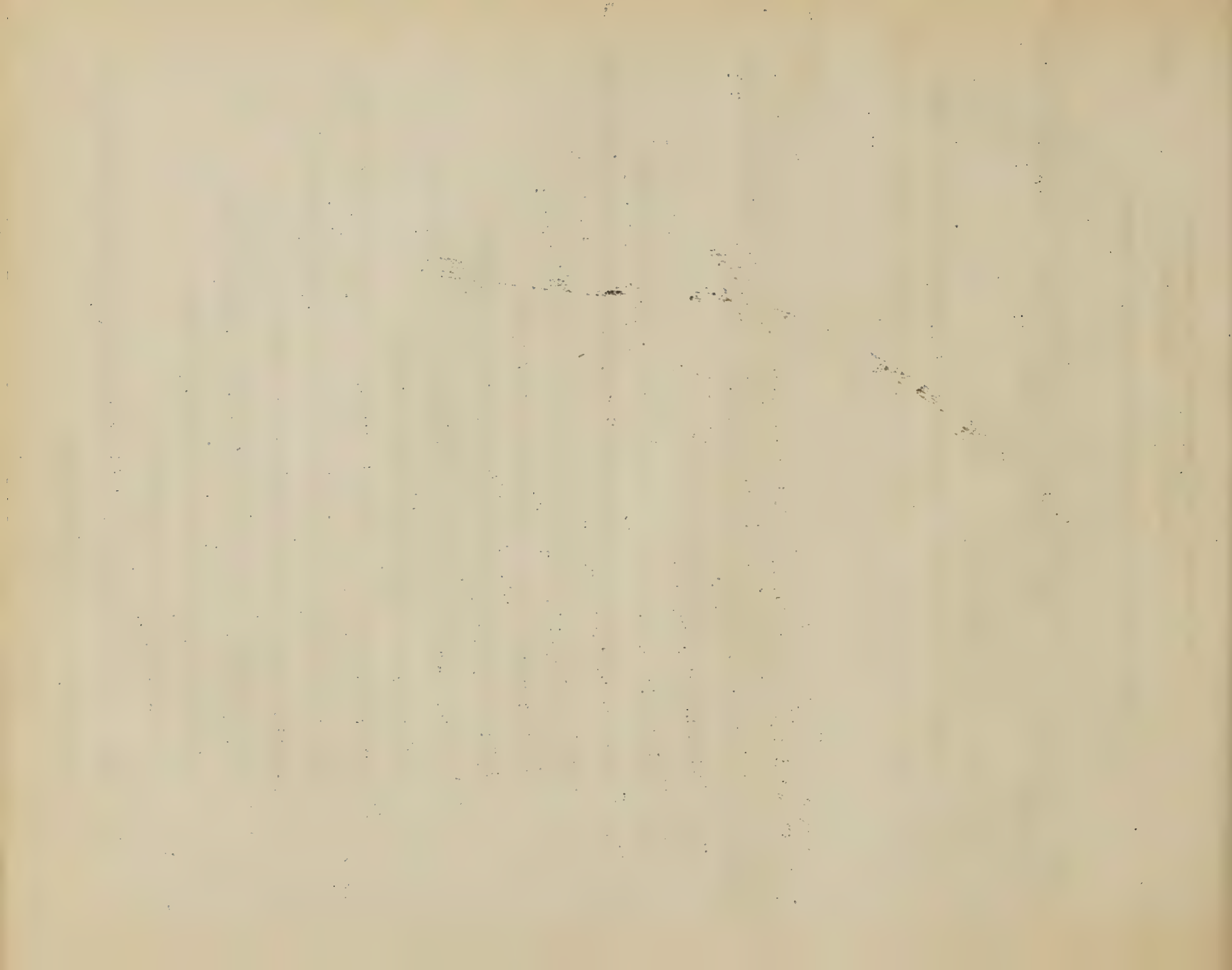
Form B.

Write a Report on the assigned work, as performed under the several items of the Given Schedule, referring to the same, by the designated numbers or letters, and treat in the following order:

1. Object of the work, in brief.
2. Methods of conducting the work and reasons for same.
3. Sketch diagrams of electrical circuits and connections used.
4. State precautions observed in conducting the work:
 - (a) In connecting the several circuits.
 - (b) In handling and in using the instruments.
 - (c) In connecting the instruments for observations.
 - (d) In use of the electrical energy.
 - (e) In operating or other work with machine or ^pappliance.
 - (f) In taking observations and making measurements.
5. Explain the possible sources of error:
 - (a) In the electrical circuits and connections.
 - (b) In the use of the electrical energy.
 - (c) In the use of instruments.
6. State the conclusions to be drawn from the observations and from the results obtained.

Forms A, B.

11.



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Requirements of Laboratory Work and Report on the Performance
of Electrical Machinery and Appliances.

Write a Report on the performance of the assigned dynamo, motor, transformer or other electrical machinery or appliance as executed under each specified item of the given Schedule, referring to the same by the designated numbers or letters; and treat in the following order:

1. Sketch diagrams of connections used for each set of operations.
2. Explain the behavior and characteristic features of the operation and performance of the machine or appliance, under the conditions prescribed for each item.
3. Describe how the regulation and control was accomplished.
4. Number and tabulate the observed readings, per given schedule, illustrating the characteristic features of operation.
5. State conclusions to be drawn from these observations referring to the instrumental readings taken for the various sets.
6. Plot curves, as specified, showing the relations between any two assigned variables; and note on same sheet what operating conditions were maintained constant.

Requirements of Laboratory Work and Report in Subject of Stray Power
and Efficiency.

Write Report of work, according to prescribed form: Form G

Plot designated curves, of the following list, on Standard squared paper; on base line of watts, or of per cent. full load (proportional part of full rated load), - of output, if dynamo, and of input, if motor is being tested:

I. Loss curves, showing individual (separated) losses, and the aggregate (total) loss, in watts, at various loads.

II. Power of Load Curves, showing:

(a) total true watts; (b) total apparent watts.

III. Idle Watts Curve, for alternating current work.

IV. Power Factor Curves, for alternating current work:

(a) Without Condenser; (b) with Condenser, in circuit.

V. Efficiency Curves:

(a) Electrical Efficiency: (b) True Commercial Efficiency:

(c) Apparent Commercial Efficiency.

VI. Volts drop at the machine.

VII. Starting Current Curves.

VIII Speed Characteristics:

(a) Shunt motor; (b) Series motor.

IX. For induction motor, plot curve of per cent. slip in speed.

X. Acceleration characteristic.

XI. Retardation characteristic.

XII. Torque curve for motors.

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Requirements of Laboratory Work and Calculations in Determination of

Stray Power and Efficiency.

1. Stray Power Losses, equal sums of watts lost in armature necessary to overcome mechanical friction, and hysteresis and eddy current losses.
2. Total Losses, equal sum of watts lost in stray power and watts lost in heating armature conductors and watts lost in field windings.
3. Gross Output, equal sum of watts available in external circuit and watts lost in heating armature conductors and watts lost in fields: equals Gross Input less the Stray Power Losses.
4. Gross Input, equals Gross Output and Stray Power Losses: equals total Lost (watts) and watts available in the external circuit.
5. Gross Efficiency, equals Efficiency of Conversion, equals Gross Output divided by Gross Input.
6. Electrical Efficiency (Economic Coefficient), equals Available Output in external circuit divided by (Gross Input less the Stray Power Loss).
7. Commercial or Net Efficiency, equals Available Output in external circuit divided by Gross Input.

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Inspection of Electrical Appliances.

1. Inspect thoroughly the assigned apparatus, appliances, device or other object set apart for such work.
2. Take apart and disconnect; re-assemble, set up, or connect as may be necessary for thorough inspection.
3. Mechanical inspection: inspect the following features and details in all instances to which they apply.
 - (a) General appearance and cleanliness.
 - (b) Freedom of movement of mechanical, electrical, or magnetic mechanisms.
 - (c) Character of adjustments necessary to operation.
 - (d) Armatures: clearance, balance, - static and dynamic.
 - (e) Lining up for operation, -- shafts, belting, etc.
 - (f) Lubrication.
 - (g) Final adjustments for operation: belt, speed, etc.
4. Electrical inspection: chiefly use of magneto and voltmeter.
 - (a) Electrical inspection by magneto.
 - (a-1) Field frame, simple grounds.
 - (a-2) Field coils, each individually, for open circuits, crosses, and grounds.
 - (a-3) Armatures: closed coil types, for open circuits and grounds; open coil types, for an open coil, crosses, and grounds.
 - (b) Electrical inspection by voltmeter.
 - (b-1) By millivoltmeter for short circuits in each field coil and in armature windings?
 - (b-2) Locate bad contacts by millivoltmeter.
 - (b-3. Inspect for quality of insulation, if injured or faulty; for approximate insulation resistance; for leakage of current under normal conditions.

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University of Illinois.

5. Inspection for short circuit in armature windings of direct or of alternating current machines.
6. Magnetic inspection: chiefly by compass needle.
 - (a) For magnetization of field or mechanism.
 - (b) For direction of magnetic polarity.
 - (c) For magnetic balance, as in armat res: radial, longitudinal.
7. Note: for primary cells and storage batteries, in- spect for
 - (a) Condition of electrolyte, quantity, quality.
 - (b) Condition of electrodes.
 - (c) State and condition of charge of storage bat- teries.
8. Note: for dynamo-electric machinery, in particular, as follows:

General:

 - (a) Sparking at brushes.
 - (b) Heating of armatures, field coils, bearings.
 - (c) Noise.
 - (d) Speed high or low.

Motor:

- (e) Stops or fails to start, direction of rotation.

Dynamo:

- (f) Dynamo fails to generate.

See A. I. E. E., Vol. XI., 1894. Parkhurst's Schedule "Dis-
cusses of Dynamos."

Operation of Electrical Appliances.

1. Thoroughly clean everything before starting any work.
2. Examine for any loose parts, fittings, connections, screws, etc.
3. Fill oil cups and insure good lubrication.
4. Adjust, line up, tighten belts to ordinary tensions, and make any other preliminary adjustments required by the work.
5. Have all switches open, cut-outs fused, obstructions cleared, and every freedom of movement necessary for successful operation.
6. Voltmeter, ammeter, pilot lights, etc., to be used, to watch building up (as of machine) or other line of preliminary operation.
7. Start up machine or apparatus, as may be necessary.
Note: For dynamos, motors, transformers, etc., see the special Operation Schedules.
8. Examine functional working of machine or apparatus, for definite results.
9. Examine performance of appliance as to regulation, control, etc.
10. Experimentally determine best operating conditions, for highest efficiency, economy, or such other feature as may be required in operation.
11. Coupling, mechanically or electrically; working in parallel, synchronizing, etc.
12. Stopping, disconnecting, and cleaning up.

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Measurement of Armature Resistances. - Dynamos and Motors.

Armature resistances can be obtained only when not running.

Method to be used, -- Fall of Potential.

Currents to be used, preferably 110 volt circuits; or Battery

Instruments: low reading voltmeter, high-reading armeter.

Precaution: armature must be connected up as a simple resistance, in series, in the circuit being used.

Regulate current used by a water resistance placed in series; or, use a lamp bank, as usual. Use heavy currents.

Take ten(10) consecutive readings of voltage across terminals and of current through armature.

Turn the armature through a small, but different angle, for each consecutive reading.

Take three sets of observations under following conditions:

I. From terminal to terminal, of machine switchboard, not including any series coil connections.

II. From brush to brush, connecting onto clips.

III. From diametrically opposite commutator segments placing voltmeter terminals under brushes.

Note:-- Measure resistance, cold, at beginning of experiment; that is, before machine is operated or before any field resistances are measured.

Measure resistance hot, after normal running, or after determination of field resistances.

Lab. Schedule 1. Mean Armature Resistances.

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Measurement of Field Resistances. Dynamos and Motors.

Field resistances may be obtained while running at normal voltage, or, when at rest, by use of suitable direct current.

Method to be used, --Fall of Potential.

Instruments, voltmeters and ammeters of suitable ranges.

(I). Resistance of Shunt Coils, of Dynamo.

- (1) Use shunt coils only. Run dynamo at usual speed. Throw in and regulate large resistance in external circuit. Run out Field Rheostat to end or to the stop. Short-circuit Rheostat at machine. Take ten(10) consecutive readings of voltage across shunt and of current through the same.

- (2) Use shunt coils and Rheostat. Run at normal speed, and voltage. Take ten(10) consecutive readings of voltage across shunt coils including Rheostat, and of current in same. Note exact position of Rheostat handle or notch. Measure exact resistance of Rheostat(including its external loads) at formerly observed position or notch. Resistance of Shunt-coils ~~Res.~~ ^{less} of (shunt and Rheostat) / Res. of the Rheostat.

(II) Resistance of Series Coils of Dynamo.

Operate dynamo as long or short compound.
Apply fall of potential method as in measurement of low resistances.
Take ten(10) consecutive readings, of voltage across series coil and of current in same.

(III) Resistance of Motor Fields.

Proceed as in (II); or,
connect ammeter to field coils at motor switchboard, take readings, as before.

Note:-- Measure resistance, cold, at beginning of experiment. Then measure field resistance, hot, after normal running.

Lab. Schedule 2. Meas. Field Resistances.

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OPERATION of Dynamos and Motors.

In General: Before starting any machine, attend to the following:

1. Thoroughly clean everything about machine.
2. Examine for loose parts, fittings, connections, brushes.
3. Fill oil cups and insure good lubrication.
4. Adjust, line up and tighten belts, to ordinary tension.
5. Have all switches open, and cut-outs fused.
6. voltmeter, ammeter, or pilot light in circuit to watch building up of machine, according to circumstances.

I. Dynamos.

A. Starting:

1. Start slowly.

2. Build up the fields.

3. Examine working, normal volts. 3. Examine working, normal speed.

4. Throw on designated load.

5. Regulate, for Norm. volts.

B. Operating:

1. Examine for any electrical

or mechanical heating.

2. Examine working of belts.

3. Operate as scheduled.

4. Watch against sparking.

C. Stopping:

1. Lower the speed.

2. Throw off load.

3. Weaken the fields.

4. Stop prime mover.

5. Lift brushes.

6. Slack Belt.

7. Stop oil circulation.

8. Clean machine; and cover.

D. Schedule of Operations.

Shunt Dynamos.

1. Regulate by Brushes.

2. Regulate by Rheostat:

(a) vary Emf., const. Load.

(b) vary Load, const. Emf.

Note: Ammeter readings.

Direction of Rotation

Reverse connections.

Reverse rotation.

A. Starting.

1. Excite fields; test same.

2. Start slowly by starting Box.

3. Examine working, normal speed.

4. Throw on designated load.

5. Regulate for normal speed.

B. Operating.

1. Examine for any electrical

or mechanical heating.

2. Examine working of belts.

3. Operate as scheduled.

4. Watch against sparking.

C. Stopping:

1. Lower the speed.

2. Throw off the load.

3. Cut armature circuit.

4. Weaken the fields.

5. Cut-out fields.

6. Lift brushes.

7. Slack Belt.

8. Stop oil circulation.

9. Clean machine; and cover.

D. Schedule of Operations.

Shunt Motors.

1. Regulate by starting Box.

(a) vary speed, const. Load.

(b) vary Load, const. Speed.

Regulate by field Rheostat.

(a) vary Speed, const. Load.

(b) vary Load const. Speed.

Regulate by arm Field Rheostat.

(a) vary speed, const Load.

(b) vary Load, const. Speed.

Note: Ammeter readings, Ext. Cir.

Direction of rotation.

Reverse connections.

Reverse motor.

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OPERATION of Dynamos and Motors, continued.

I. DYNAMOS.

D. Schedule of Operations.

Series Dynamos.

1. Regulate by brushes.
2. Regulate by controller.

- (a) Vary Amp., Const. Load.
- (b) Vary Load, const. Amp.

Note: Voltmeter readings.

D. Schedule of Operations.

Series Motors: Const. Cur. Circuit.

1. Regulate by Commutating Field.
 - (A) Vary speed, const. Load.
 - (b) Vary Load, const. Speed.
2. Regulating Field Shunt.

Same runs as preceding.

Note: Voltmeter readings.

Direction of rotation.

Reverse connections.

Reverse rotation.

Series Motors: Const. Potent. Cir.

1. Regulate by Commutating Fields.

- (a) Vary speed, const. Load.
- (b) Vary Load, const. Speed.

2. Regulate by starting Box.

Same runs as preceding.

Note: Ammeter readings.

Direction of Rotation.

Reverse connections.

Reverse rotation.

Compound Motors.

Compound Dynamos.

1. Follow schedule for Shunt Dynamos.

2. Note action and Emf. connected up in long and short shunt.

3. Regulate degree of compounding by series shunt. Vary Emf. at var. Load.
 - (a) Undercompound.
 - (b) Flat compound.
 - (c) Over compound.

4. Examine the effect of Differential compounding.

Separately-Excited Dynamos.

Examine effect of variable loads at constant excitation. Voltmeter readings, Ext. circuit. Direction of Rotation. Reverse field.

Separately-Excited Motor.

Examine effect of variable armature Emf., with constant excitation of fields. Same variable Arm. Current. Take suitable readings. Direction of Rotation. Reverse Arm. connections.

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OPERATION of Dynamos and Motors, continued. The Ward-Leonard System.

Object: To operate an electric motor at almost uniform efficiency with ranges of speed and torque.
To secure large starting torque and at the same time high efficiency.

Preliminary.- Make preliminary run at greatest load to ascertain if the machines are adapted to each other and of proper capacity.

Operate.- Carry through a series of tests to determine for plotting curves noted below. Operate the motor reversed.

Plot curves, showing characteristic relations between the two assigned variables, on the same base where convenient.

Series A. In illustration of law:

- (1) That the speed of motor varies directly as Emf. in usual formula.
- (2) That the torque of motor varies directly as the armature current, unusual formula.

Series B. The following efficiencies to be determined, not electrical in-input of the motor and measured brake power.

- (3) Efficiency at constant speed, on torque base.
- (4) Efficiency at constant torque, on speed base.

Series C. The following efficiencies to be determined from gross electrical in-input of the system.

- (5) Efficiency at constant speed, on total watts in-input base.
- (6) Efficiency at constant torque, on total watts in-input base.

Series D. The following efficiencies to be determined from gross electrical in-input of the system when motor is operated by usual rheostatic control.

- (7) Efficiency at constant speed, on total watts in-input base.
- (8) Efficiency at constant torque, on total watts in-input base.

Series E.

- (9) Separate aggregate losses of each machine required in the Ward-Leonard system, and plot these and available out-put on total watts in-input base.

Reference: Transactions of the Am. Inst. Elect. Engineers, Vol. XIII 1896, page 377. "Volts vs. Ohms.", by H. Ward-Leonard.

Lab. Schedule 4---0

Ward-Leonard System.

1. Operating conditions:

- (a) Operate assigned machine under the conditions specified in table below for required characteristic.
- (b) Brushes to be adjusted to proper position and must not be shifted during the experiment.
- (c) Field rheostat to be adjusted to proper position, and not to be changed during experiment, except as required by such specific characteristics as are shown in table below.
- (d) Adjust controlling devices before beginning and do not alter these during the experiment.
- (e) Apply all loads very gradually.

2. Preliminary: take a few preliminary readings to examine the operation of the machine.

3. Instrumental readings:

- (a) Take readings for all values, constant or variable.
- (b) Take successive readings, by regular instruments, of volts or amperes, according to characteristic being determined.
- (c) Record readings only:
When conditions are exactly as specified.
When machine is operating uniformly under steady conditions.
When constant readings are given by the instruments.

4. Precaution: do not retrace any of the work, even if the reading has not been taken at the exact increment of load intended.

Table of Operating Conditions for Dynamo Characteristics.

Electrical Characteristics.	Type of Machine.	Posit. of Rheost.	Fd. Cur.	Ext. Cur.	Tot. Cur.	Emf. Term.	Emf. Tot.	Rpm.	Nichols
Armature.----	Shunt.	v	V-Y	V.X	v	C	v	C	Exp. 5.
External.----	Series Shunt. Comp'd.	C	v	V.X	v	V.Y	v	C	Exp. 3, 4, 6.
Regulation(Ext.)	Sep. Exc.	v	C	V.X	v	V.Y	v	C	
Internal.---- (Mag. Curve).	Series. Shunt.	c	V.X	c	V	V.Y	v	C	Exp. 3, 4, 6.

Letters signify:

C---values to be maintained constant during experiment.

c---values which will be constant.

V--- primary variables to be observed and between which the characteristic curve is to be plotted.

v---secondary variables, operating variables, but not required readings.

COUPLING: Operation of Direct Current Dynamos and Motors in Series and in Parallel.

A.--General Conditions:

- (1) Machines to be of same type, usually of same size.
- (2) Compound machines, in general, of same type of Compounding.

B.--Switching-in Conditions:

- (1) Direction of current flow should be the same:

Plus to plus for parallel coupling.

Plus to minus for series coupling.

- (2) The Emf. or current to be constant, and the same, for each machine before switching-in, according to the specific combinations noted in table below.

C.--Operating Conditions:

- (1) Speed to be maintained uniform under all conditions.

- (2) Equalize or proportion the loads on the several machines by field rheostats or regulators, as case may be.

D.--Operation of Machines, as Coupled:

- (1) Operate at different loads, up to maximum for combined output, and examine for satisfactory working.

- (2) Where equalizer is used, maintain current in it at a minimum, under all conditions of load, for machines of same size, and note working by an equalizer ammeter.

E.--Unbalanced loads:

- (1) Show that a shunt machine in parallel may become a motor if its Emf. be sufficiently lowered; it continues to revolve in same direction, taking current from line.

- (2) Illustrate effect of balancing-unbalancing three-wire system, by neutral ammeter, and by lamp bank.

Schedule of Operating Conditions and Connections for Coupling.

Machines Coupled: Conditions: Connections.

	Emf.	Cur.	Field.	Armature:	Mach. Terminals
1. Shunt: parallel.	same	Var	Indep. Excite.	-----	To line, in Par.
2. series, 2w	Var.	Same	(a) In series.	in series	" " in Ser.
			(b) Indep. Exc.	" "	" " in Ser.
3. series, 2w	same	Var.	Indep. Excite.	-----	" " in Ser.
Series: parallel				-----	neutral between
4. with Equalizer	same	Var.	In Par. with Equal & line	In Par. Eq. & line	To line, in Par.
5. Mut. Excited.	same	same	Each Fd. in Ser. with other Arm.	-----	To line, in Par.
5a. Ser. Series	Var.	same	In series with Sh. Ind. Exc.	Arm. in Ser.	" " in Ser.
6. Compound: Para	same	Var	Ser. in Par. Eq. & line.	-----	To line, in Par.
			Shunt same as Case (2)	-----	" " in Ser.
7. Series, 2w.	Var.	same	Ser. Fd. in Ser. with Arm	-----	To line, in Ser.
			Indep. Excite.	-----	" " in Ser.
8. Series, 3w.	Same	Var.	Ser. Fd. in Ser. with arm.	-----	To line, in Ser.
				-----	neutral between

COMPOUNDING MACHINES.

Objects of Compounding:

- (1) To get a flat or over-compound external characteristics at constant speed and under variable loads.
- (2) To operate machine at a different speed from that originally intended, necessitated by either belt ~~slip~~ ^{spit slip} or slight alteration in speed of prime mover.
- (3) To compensate for line drop as load increases so as to maintain ~~terminal~~ terminal voltage constant.

Preliminary Data to be obtained:

- (1) Number of turns, total, of the shunt field coils.
- (2) Speed at which compounding is intended to be effective.

Preliminary Work:

(1) Determine number of shunt turns by comparative method:

- (a) Separately excite the machine, use a special auxiliary shunt field winding, and determine the F_{mf} . and field currents at normal Rpm. and no load.
- (b) Separately excite the machine, using regular shunt field windings, and determine field current at same F_{mf} . as in preceding (a), at normal speed, no load.
- (c) Total ampere turns will be same in each case, (a) and (b), preceding. Therefore find the number of turns on the original shunt field winding.

(2) Obtain armature characteristic for assigned voltage. Determine relation and plot curve between external and field current, operating as a shunt machine, under assigned conditions:

- (a) Normal speed, constant voltage.
- (b) Normal speed, 5% rise in voltage.

Work of Compounding the Machine:

- (1) Compute required turns of series coil from the preceding armature characteristics.
- (2) Compensate by a series shunt for 2% variation in speed, from the normal. Add enough turns to series coil to give desired compounding at speed 2% below normal Rpm.
- (3) Determine proper resistance of series shunt, from predetermined series winding, to give normal compounding at normal speed, and still allow for 2% variation in speed.

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MOTOR-GENERATOR TEST.

Measurement of Stray Power and Efficiency by Motor-Generator Method, of Hopkinson's Circulating Test, based on the assumption that the stray power losses are the same in each machine, which will usually be the case when the condition is fulfilled that the two machines are of the same type and size, and of the same kind of compounding.

Connect two machines in series, one as a dynamo, the other as motor, and supply loss by auxiliary dynamo.

Operating Conditions: (1) Uniform speed of dynamo.

(2) Maintain constant potential between the machines.

Preliminary: Run to see if the two machines can be operated together throughout ranges of loads intended.

Measurements: Series of readings from zero to full load.

Precautions:

(1) Insert fuses in main supply and interconnected circuits.

(2) Note instructions, of Schedule 7, for the operation of dynamos and motors in series and in parallel.

(3) Exercise special care in the use and adjustment of the field rheostats and brushes of each machine.

CIRCUIT WORK.

Object: to make a study and inspection of transmission and distribution circuits, accessories and appliances, examine their electrical and mechanical condition, and make voltmeter measurements of drop and insulation resistance; all with particular reference to the requirements of installation and insurance rules, and the regulations of the National Board of Fire Underwriters, as published in the National Electrical Code.

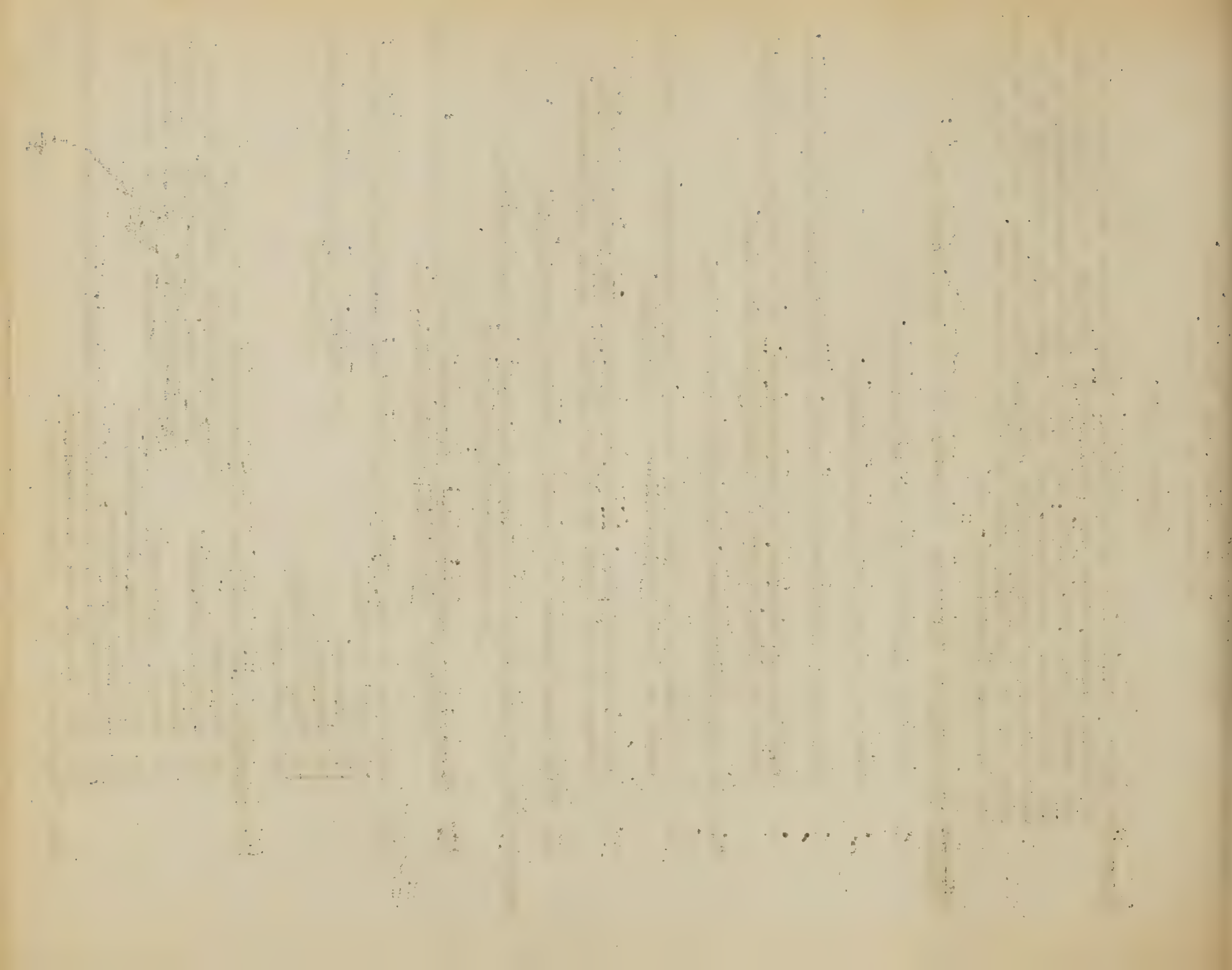
Inspect the assigned circuits, or parts of the same, noted below:

- A. From the generator to the switchboard.
- B. Circuits at and on the switchboard.
- C. From the switchboard to grounds, for detectors and arresters.
- D. From the switchboard to transformer, or to feeders and transmission line, where no transformers are used.
- E. At the transformers, at either end of line.
- F. The transmission line, or feeder, from switchboard to switchboard or from transformer to transformer.
- G. Distribution system, from the distributing point, or transformer to the lamps or motor service; mains and branches.
- H. From transformers to ground; grounded secondaries.

Examine one or more of the following features of the circuits, as may be specified or required:

- (1) Mechanical imperfections; imperfect or loose contacts, joints, fittings, junctions, connections, etc.
- (2) Condition of the electrical circuits; localization of faults:
 - (a) Open circuits.
 - (b) Crosses.
 - (c) Grounds.
 - (d) Short circuits.
 - (e) Burn outs.

Use magneto and high resistance voltmeter.
- (3) Character and condition of accessories and appliances:
 - (a) Switches.
 - (b) Circuit breakers.
 - (c) Fuses.
 - (d) Ground detectors.
 - (e) Synchronizing arrangements.
 - (f) Lightning arresters.
 - (g) Instruments and accessories, shunts, multipliers, transformers.
 - (h) Regulators and compensators.



CIRCUIT WORK.

- (4) Condition of insulation, of insulators and of insulating materials used in the constructive work of installation.
- (5) Measure insulation resistance of assigned portions; Plate 4.
- (6) Measure ground leaks and resistance of grounds.
- (7) ~~Make~~ an electrical survey of a district where leakage of current is suspected, resulting in electrolysis of underground pipes for gas, water, etc. Plate 54.
- (8) With an Inspector's set, for voltage and wattage measurements, examine lamps through the distributing system, as specified. If lamps are not all of same rated voltage, determine if proper lamps have been placed at the given point of observation. Also, watts consumed per lamp.
- (9) Determine Drop in voltage, as follows:
 - (a) At each stage of the distribution, or each portion of the circuit, as may be specified, at assigned loads.
 - (b) Examine difference in voltage between any two lamps of the same distributing system or net work: it should not exceed two per cent. of supply voltage.
- (10) Determine where subfeeders might advantageously be introduced into the system, if deemed necessary, that a network might be formed:
 - (a) In a direct current system.
 - (b) In an alternating current system.
What is the determining factor in each case of network distribution or feeding?

Requirements of Report: Follow Form B., and note following:

- (a) Diagram of the circuits examined.
- (b) Draw up and fill in an inspection schedule for each circuit or portion of circuit examined, similar to following:
Designation of circuit.
Length of circuit, in feet.
Size of wire used on circuit: (B & S gauge).
Distance apart of wires, of same circuit:
of different circuits:
Resistance of circuit, at given load:
Impedance of circuit, at given load.
No. of cycles, if A.C. is used.
Volts, at distributing point,
at receiving point:
drop in portion of circuit.
drop, calculated:
drop, in per cent. of normal:
Amperes, normal, or given load:
Remarks, location of faults, etc.

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Measurement of INDUCTANCES. - Joubert's Method; and Am. & Va. Method.

Direct comparison, with known or measured non-inductive resistance, in series with inductance to be measured, whose resistance is also known.

Alternating current, approximately sinusoidal; 110 volts.

Measurements.

(1) By direct current, fall-of-potential-method, measure resistances of inductive and non-inductive branches.

(2) With alternating current, measure fall of potential, along inductive E_L and non-inductive E resistances; and current (I).

(3) Determine the frequency of the alternating current.

Instruments: D.C. ammeter and voltmeter, for resistance measurement.

A.C. voltmeter with negligible inductance.

A.C. ammeter, for current in circuit.

Precaution: currents used must not heat resistances, appreciably. Frequency determinations must be simultaneous with reading of instruments.

A.C. instruments must not be left in circuit.

A.C. supply to be steady, if iron is in circuit.

Take ten (10) consecutive readings for D.C. and A.C. determinations respectively; find arithmetical average and apply Least Squares.

In Joubert's Method, apply following formula:

(a) E_L and R_L and E and R being respectively, Emf. and resistances in ohms of inductive and non-inductive circuits.

f , the frequency.

L , the inductance to be found in henrys.

$$E_L = I(R_L^2 + 4\pi^2 f^2 L^2)^{1/2}$$

$$E = \frac{I R}{L}$$

(b) In Am. and Va. method, apply formula, as usual, for an alternating current flowing in an inductive circuit, from which the impedance and reactance is to be found, analytically and graphically.

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Determination of ANGLE of LAG.

The Angle of Lag may be determined from its cosine, by measuring the true watts of the alternating current, and dividing by the apparent watts.

Alternating current: approximately sinusoidal: 110 volts.

Measurements: measure the true energy of the circuit, by wattmeter; measure the apparent energy of the circuit, by usual A.C. ammeter and voltmeter.

Instruments: A.C. Wattmeter, high resistance, non-inductive.

A.C. Voltmeter, high resistance, non-inductive.

A.C. Ammeter.

Precautions: A.C. Wattmeters and voltmeters, must not be used with more than 75% of the maximum allowable scale reading of the pressure coils.

Character of the circuit under examination must not be changed during the time.

Take five (5) consecutive readings, throughout, with three different kinds of inductive loads, in circuit.

Note: If curves of Emf. and of current are at all irregular, then the result found above will be the angle of lag between the equivalent sine curves.

Apply usual methods for analytical and graphical solution.

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POWER and POWER FACTOR of Alternating Current.

The Power Factor will be determined from the angle of lag, at various loads which are to be measured by the usual methods for determining the true and apparent watts.

Two Methods will be used:

A. By the use of indicating instruments, only.

Follow Schedule A.C. #203, for series of different loads.

B. By the use of Integrating Wattmeters.

(1) Follow Schedule, A.C. #203, for measurements with A.C. ammeter and A.C. Voltmeter of the apparent watts.

(2) Use Integrating Wattmeter of suitable range.

Make a series of runs, at constant loads, for definite time intervals, respectively.

Make measurements of Power and determinations for Power Factor by five

(5) consecutive readings, at each of five different loads.

In this experiment, neglect the power consumed by the Wattmeter.

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Measurement of CAPACITY.-- Ammeter and Voltmeter Method.

Direct comparison with known or measured non-inductive resistance, in series with the capacity to be measured.

Alternating current, approximately sinusoidal; 110 volts.

Measurements:

- (1) By direct current, fall-of-potential method, measure resistance of non-inductive branch.
- (2) With alternating current measure fall of potential (E_C) across condenser terminals; and fall of potential (E) Along non-inductive resistance; and current (I).
- (3) Determine the frequency of the alternating current.

Instruments: D.C. Ammeter and voltmeter, for resistance measurement.
A.C. Voltmeter with negligible inductance.
A.C. Ammeter, for current in circuit.

Precautions: Currents used must not heat resistances, appreciably. Frequency determinations must be simultaneous with reading, of instruments.
A.C. instruments must not be left in circuit.
A.C. supply to be steady.

Take ten(10) consecutive readings for D.C. and A.C. determinations respectively; find arithmetical average and apply Least Squares.

In this method apply following formula:

(a) E_C being the condenser Emf.

resistance of condenser is zero;

E and R being respectively Emf. and

resistance of non-inductive portion of the circuit.
 n = the frequency

c , the capacity to be found, *in farads*.

$$\frac{E_C}{E} = \frac{1}{I \cdot R} \left(\frac{1}{2\pi n c} \right)$$

(b) In this Am. and Vm. Method apply the formula, as usual, for an alternating current flowing in a circuit containing resistance and capacity, as in this case, from which the impedance and reactance are to be found, analytically and graphically.

(c) Otherwise measure frequency (n), current (I) through the condenser and fall of potential (E_C) across condenser terminals and apply formula: $I = \frac{E}{\sqrt{R^2 + \frac{1}{n^2 c^2}}}$, from which find capacity C .

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INDUCTANCE or CAPACITY in Series and in Parallel.

Determinations of the resultant Emf. (for series combinations) and of the resultant current (for parallel combinations) in circuits containing only:

A.- Inductance; or B. Capacity.

Alternating current approximately sinusoidal, 110 volts.

Measurements:

- (1) By direct current, fall-of-potential method, measure resistance of non-inductive branch.
- (2) With alternating current measure fall of potential (E_C) across condenser terminals; and fall of potential (E) along non-inductive resistance; and current (I).
- (3) Determine the frequency of the alternating current.

Instruments: D.C. ammeter and voltmeter, for resistance measurement.
A.C. voltmeter with negligible inductance.
A.C. ammeter, for current in circuit.

Precautions: currents used must not heat resistances, appreciably.
frequency determinations must be simultaneous with reading of instruments.
A.C. instruments must not be left in circuit.
A.C. supply to be steady.

Combinations to be made as follows for each case: A., of inductances; and B, of Condensers.

I.-

1. In series, without non-inductive branch.
2. In series, with non-inductive branch.

II.-

1. In parallel, without non-inductive branch.
2. In simple parallel, with non-inductive branch.
3. In series parallel, with non-inductive branch.

Constructions for each case A and B the individual and resultant.

- I. Emf. triangles for all series combinations.
- II. Current triangles for all parallel combinations.

Lab. Schedule A.C. 206. Inductance or Capacity.

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INDUCTANCE and CAPACITY in Series and in Parallel.

Determination of the resultant Emf. (for series combinations) and of current (for parallel combinations) in circuits containing both inductance and capacity.

Alternating current, approximately sinusoidal: 110 volts.

Measurements:

(1) By direct current, fall-of-potential method, measure resistance of non-inductive branch.

(2) With alternating current measure fall-of-potential (E_0) across condenser terminals; and fall of potential (E) along non-inductive resistance; and current (i).

(3) Determine the frequency of the alternating current.

Instruments: D.C. ammeter and voltmeter, for resistance measurement.

A.C. voltmeter with negligible inductance.

A.C. ammeter, for current in circuit.

Precautions: currents used must not heat resistances, appreciably. frequency determinations must be simultaneous with reading of instruments.

A.C. instruments must not be left in circuit.

A.C. supply to be steady.

Combinations to be made as follows for each case of

A.- Inductance greater than capacity.

B.- Inductance equal to capacity.

C.- Inductance less than capacity.

I.

1.- In series, without non-inductive branch.

2.- In series, with non-inductive branch.

II.

1.- In parallel, without non-inductive branch.

2.- In simple parallel, with non-inductive branch.

3.- In series parallel, with non-inductive branch.

Construct for each case A, B and C, the individual and resultant

I. Emf. triangles for all series combinations.

II.- Current triangles for all parallel combinations.

Lab. Schedule A.C. 207. Inductance and Capacity.

TRANSFORMER OPERATIONS.

A.- Study of Transformers.

B.- Inspection of Transformers. See INSPECTION, Lab. Schedule 0.2, sheets 1 and 2; special inspection by magneto and voltmeter.

C.- Operation of Transformers.- See OPERATION, Lab. Schedule 0.4.

- 1.- General condition: Transformers to be of same type and size, and of ratios adapted to combination desired.
- 2.- Operating condition of a single Transformer, with divided circuits:

(a) The primary and secondary coils of transformer to be connected in series or in parallel, as required by its use, and examined by high reading voltmeter, or by two lamps, to determine if Emf.'s have been added or subtracted.

(b) For Scott Phasing Transformers, connect main and teaser taps, examine main and teaser terminals to determine which of the latter is to be dead-ended.

3.- Switching in conditions: of two or more transformers:

- (a) Direction of current flow should be the same; plus to plus for parallel; plus to minus for series coupling.
- (b) The Emf. or current to be the same, for each transformer according to the specific combinations noted in the schedule below.

Connect primaries, as required by combination being made; connect one side of each secondary and examine voltage across free ends of secondaries, by high reading voltmeter, or two lamps to determine if Emf.'s have been added or subtracted.

4.- Operating Conditions of Transformers, as coupled:

Operate at different loads, to the maximum for combined output, and examine heating and regulation for satisfactory working.

5.- Unbalanced loads, on two-circuits, 3-wire systems:

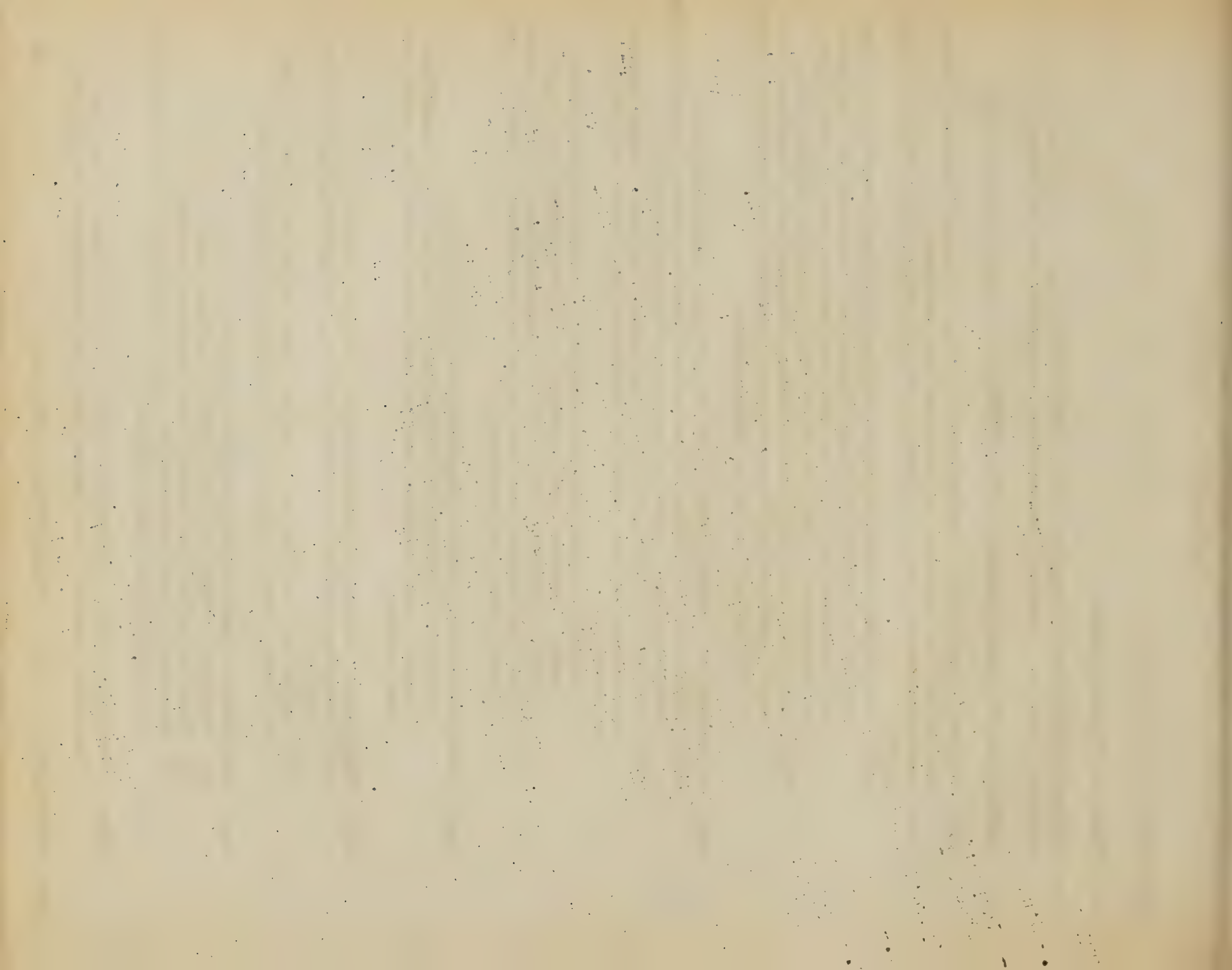
- (a) Illustrate effect of unbalancing, by neutral ammeter or lamp bank.
- (b) Illustrate effect of blowing fuse on one-half of 3-wire system, from a single divided-circuit transformer.

6.- Unbalanced loads on Polyphase circuits.

- (a) Examine effect of unbalanced 2-phase system.
- (b) Examine effect of unbalanced 3-phase system.
- (c) Examine effect of reduced transformer ratio or open circuit in three-phase system.

Note: Primary coils, the small wire high resistance windings.

Secondary coils, the large wire low resistance windings.



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TRANSFORMER TESTING.

- A.- Resistances of Primary(High resistances) and Secondary (Low Resistance) Coils.- See Lab. Schedules 1 and 3, Resist. Tests.
- B.- Inductance of Transformer and its variations with different degrees of saturation. See Lab. Schedule A.C. 201.
- C.- Angle of Lag, Power and Power Factor of alternating current through transformer. See Lab. Schedule A.C. 203, 204.
- D.- Transformer Testing:
Operating Conditions: Primary voltage must be steady.
Apply all loads gradually on secondary circuit.
Preliminary run to examine operation and range of apparatus.
- 1.- Regulation or External Characteristics.
Readings: Primary voltage, to be maintained constant.
Secondary current and voltage at variable loads.
- 2.- Power factor curve: See Lab. Schedule A.C. 204.
- 3.- Loss Curves: to be determined as follows; and
(a) Copper losses, from ammeter measurements given or known resistances of primary and secondary coils.
(b) Iron Losses, by following readings on open circuit secondary:
(1) ammeter, to correct for small and usually negligible copper losses.
(2) wattmeter, to determine total losses in transformer.
- 4.- Efficiency, to be determined by the following methods:
(a) Simple wattmeter method, by simultaneous wattmeter measurements in primary and secondary.
(b) Stray power method, compute the efficiency from the above determined copper and iron losses.
(c) Sumpner's circulation method, or differential method: Two similar transformers, same type and size. Primaries of the two transformers short circuited on themselves, in series.
Secondary of one transformer, in parallel across the mains; secondary of the other transformer in series with secondary of an auxillary transformer and a wattmeter, and all three in parallel, across the mains.
Ammeter, voltmeter and wattmeter in main circuit.

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COUPLING (SYNCHRONIZING) ALTERNATORS.

A.- General Conditions:

- (1) Alternators to be of the same type and similarly driven by the same kind of prime mover (steam or gas engines, turbines or motors).
- (2) Composite alternators to have same type of composite windings.
- (3) Circuits from machine to be of same phase, voltage and frequency.

B.- Synchronizing Lamps.

Connect for each machine synchronizing lamp or lamps (of total voltage equal to that of machine) in series with the synchronizing bus bars or in series with similar arrangement at other machine (if they are only two machines to be coupled), with plug or switch to cut out lamps at any time. Total voltage of all lamps in series equal twice the voltage of machines synchronized.

Single phase circuits require only one set of lamps arranged, as above described, for each machine.

Two and three-phase circuits, require a set of synchronizing lamps in each phase, unless they have previously been made symmetrical in each phase and the connections for synchronizing thence made permanent.

C. Synchronizing Switch.

Provide synchronizing switch between the leads of the two machines; and if they are more than two machines, such a switch to be provided between machine and bus bar; and, in any case synchronizing switch must throw in all phases at once.

D.- Starting:

Machine to be coupled must be driven by independent prime mover and brought up to synchronous speed, usually without load.
Bring up voltage to that of other machine or of the bus bars.

E.- Switching-in Conditions, or Synchronizing:

Plug in the synchronizing lamp or lamps for each machine, before synchronizing speed is reached.

As synchronous speed is reached, watch when lamps go out.

Throw synchronizing switch during a long interval when lamps are out, at which time the machines are in synchronism.

Machines are usually synchronized with no load on them.



COUPLING & SYNCHRONIZING) ALTERNATORS.

F.- Examination of Synchronizing Conditions:

- (1) Effect of load, if any, on the machine at time it is switched in
(a) Empty; (b) lightly loaded; (c) heavily loaded.
- (2) Character of main circuit, that of bus bar or other machine:
(a) Lagging; (b) Leading; (c) Unity power factor.
3. Character of circuit of machine to be synchronized:
(a) Lagging; (b) Leading; (c) Unity power factor.
- (4) Symmetrical and unsymmetrical, two or three-phase circuits:
Examine branches of armature circuits, for symmetry, and determine how to synchronize if armature circuits are unsymmetrical.
- (5) Balanced and unbalanced, two or three-phase circuits:
Determine how to synchronize and couple if main of bus circuits are unbalanced.
- (6) Switching in two or more machines, under any one of the preceding conditions.
- (7) Switching in machines in composite working.

G.- Operation of Alternators in Parallel:

(See, Schedule of Operation, 0.4, for all features of work applying to this which are not included in electrical lines.)

- (1) Character of load variations and part taken by each machine.
- (2) Character of external circuit load,
(a) Lagging; (b) Leading; (c) Unity power factor.
- (3) Character of phase loads, on two and three-phase circuits:
(a) Balanced phase loads; (b) Unbalanced phase loads.
- (4) Effect on satisfactory working of alternators in parallel, of:
(a) Method of driving alternators, direct connected to prime mover or belt driven.
(b) Size of prime movers.
(c) Method of regulation of prime movers.
- (5) Determine best operating conditions for alternators in parallel in each of the above cases with particular reference to the effect of unbalanced circuits; different methods of driving and regulation of prime movers.

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SYNCHRONOUS MOTOR WORKING.

A.- Starting Conditions:

- (1) Start, with motor in synchronism, at very low speeds, and slowly increase speed of generator, to prevent motor falling out.
- (2) Start by running up to synchronous speed, driving motor from any source of power, and throwing into line with generator when motor is in synchronism, as shown by synchronizing lamps.

B.- Operating Conditions:

- (1) Show that by changing the excitation of synchronous motor, the phase of the line current is shifted, and as follows, for a given or fixed load on the motor:
- (a) Weak field excitation, current lags, large value for work.
 - (b) Moderate field excitation, current may be brought into phase with impressed Emf., giving unity of power factor and minimum line current, and maximum efficiency.
 - (c) Stronger field excitation, current becomes leading, and increases in value for work (given) done.
- (2) - Show that by changing the load on the synchronous motor, the phase of the line current may be shifted, and as follows, for given degrees of field excitation.
- (a) Weak field, motor rather under-excited, power factor simply reaches a minimum, but does not become unity.
 - (b) Moderate field excitation, (the most desirable one), the current lags behind impressed Emf. at small loads, comes into phase with it, at about average load, and lags again at heavier loads owing to its leading the Imp. Emf.
 - (c) Strong field excitation, current leads the Imp. Emf. at all light and moderate loads, passes through zero lag, and then lags more and more; maximum loads.
- (3) - Show how to hold power factor close to unity, as any load changes, by suitable variation of field excitation.
- (4) Show that synchronous motors will work, with given output, and at same Arm. current, with two different degrees of excitation, in one case with leading and in the other case with lagging current.
- (5) Show when an over-excited synchronous motor acts like a condenser on the transmission line, and work it in circuit with an induction motor to raise the power factor of the line.
- Show that an overloaded polyphase synchronous motor that falls out of step, can quickly be brought up to speed and into step, by relieving slightly of the load.

INDUCTION MOTOR WORKING.

A. Starting Conditions:

(1) Single Phase Induction Motors:

- (a) Examine Auto-transformer in starting these motors.
- (b) Examine use of phase splitting, by use of resistance and reactance, in external circuit of single phase motor.

(2) Polyphase Induction Motors.

Examine starting conditions for 2-phase and 3-phase motors.

(3) Starting Current and Torque, in general.

- (a) Show that large starting currents are required.
- (b) Show that the starting current is reduced by lowering the impressed Emf., and at the sacrifice of starting torque.
- (c) Determine what starting loads, and what full and overloads, the given machine is adapted to take, under given conditions of electrical supply, and possible variations in impressed Emf.

B.- Operating Conditions.

- (1) Show that the slip, in speed; of induction motors, increases with the load applied.
- (2) Show that in an overloaded induction motor, the speed and torque rapidly fall off, while excessive current is required.
- (3) Show when an overloaded motor will stop; how started again?
- (4) Show how speed of induction motor may be varied by varying the impressed Emf., by use of an external reactance or compensator on motor possessing high fixed armature resistance.
- (5) Show that power factor of the circuit, at full load of induction motor, remains practically unchanged with ordinary variations in the impressed Emf.
- (6) Show that an induction motor may be advantageously used in connection with a synchronous motor on same line, to raise power factor by synchronous motor performance as condenser.
- (7) Polyphase Induction Motor.— Open one leg of circuit, motor in normal running conditions, and determine following points:
 - (a) Allow motor to slow down, by opening line switches, close the same and determine point below which the induction motor, so operated, will not start up again.
 - (b) Show that the same motor cannot be started up from rest, under these conditions.



ROTARY CONVERTER WORKING.

1. As Direct Current Motor; Alt. Cur. Dynamo. See Operation of dynamos and Motors, Lab. Schedule 4 (1.2).

- (a) Examine starting conditions, polarity of fields, rotation.
- (b) Show that an inductive load thrown on A.C. side, weakens field and machine speeds up.
- (c) Show opposite effect, when synchronous motor is thrown into service, to give leading currents, operating as a condenser on the line.
- (d) Show how to secure satisfactory operating conditions of the rotary, whether lagging or leading currents are thrown back into it, from the A.C. side.
- (e) Illustrate regulation of the rotary with lagging or leading currents on A.C. side.

2. As Alt. Cur. Motor: Direct Current Dynamo. (See Synchronous Motor Working, A.C. Schedule 215 A).

- (a) Examine starting conditions, polarity of fields, rotation:
 - (a) As induction motor;
 - (b) brought up to synchronism as D.C. Motor.

- (b) Examine effect of the performance of the rotary when lagging or leading currents are supplied: respectively:
 - (a) effect on the speed.
 - (b) effect on rotary fields.
 - (c) effect on D.C. voltage.

(c) Examine the so-called "pumping" effects.

- (d) Examine effects of heavy and variable loads on rotary, as in Street railway working. Show how to build up D.C. voltage under heavy loads.

(e) Determine best operating conditions for unity power factor.

- (f) Show that the power factor remains practically constant at all loads, in case of shunt wound machines, under best operating conditions.

ELECTRIC LIGHTING.

Electric Light and Lighting.

Advantages and disadvantages of electric illumination; open and enclosed arc lighting and incandescent systems.

Effects of Frequency.

Comparative costs of different systems of artificial illumination.

Photometry.

Units, standards and measurements.

Incandescent Lighting.

Incandescent filaments, action and illuminating power.

Photometry of the incandescent light, characteristics of candle power and distribution.

Filaments.

Materials used, bamboo, cotton, cellulose.

Preparation, carbonization, flashing, mounting, treating.

Shapes of filaments, straight, looped, spiral.

Incandescent Lamps.

Manufacture, exhaustion, scaling, mounting, etc.

Blackening of bulb, age coating.

Incandescent Lamp Accessories and Interior Wiring.

Fittings and fixtures, bases, sockets, cut-outs, fuses, regulative devices.

Incandescent Light Distribution.

Series and parallel, alternating and direct current systems.

Three-wire systems.

Protective and safety devices, lightning arresters, fuses, circuit breakers.

Switch-boards and regulative devices, wiring, instruments, regulative devices.

Incandescent Lamp Economics.

Inspection, color, of filament

Efficiency, life, age, smashing point. , spots, vacuum.

Application of Incandescent Lighting.

Interior and exterior, residences, public buildings, streets, etc.

ELECTRIC LIGHTING.

Lighting has long been a problem for the architect and the engineer. The problem is not only to provide light, but to provide it in a way that is efficient, economical, and pleasing to the eye.

The problem of lighting is a complex one, involving many factors. The first factor is the type of lighting required. Is it for general illumination, or for task lighting, or for accent lighting?

The second factor is the location of the lighting. Is it for a large room, or for a small room, or for a specific area?

The third factor is the type of lighting fixture. Is it a recessed fixture, or a surface-mounted fixture, or a pendant fixture, or a track fixture?

The fourth factor is the type of lighting source. Is it incandescent, or fluorescent, or LED, or halogen?

The fifth factor is the cost of the lighting. Is it for a budget, or for a premium, or for a middle ground?

The sixth factor is the life of the lighting. Is it for a short life, or for a long life, or for a middle ground?

The seventh factor is the maintenance of the lighting. Is it for a low maintenance, or for a high maintenance, or for a middle ground?

The eighth factor is the energy efficiency of the lighting. Is it for a low energy efficiency, or for a high energy efficiency, or for a middle ground?

The ninth factor is the aesthetic appeal of the lighting. Is it for a plain, or for a decorative, or for a middle ground?

ARC LIGHTING.

Electric Arc.

The voltaic arc, striking, maintenance of arc.

Photometry of the arc, characteristics of candle power and distribution.

Carbons .

Manufacture, quality, size, shape, solid, cored.

Rate of consumption, alternating and direct current.

Regulative Mechanism.

Series and shunt magnets, differential and compound magnets.

Striking mechanisms and automatic cut-outs.

Arc Lamp.

Open or enclosed arcs for alternating or direct current service, and for constant current or constant potential distribution.

Single or double carbon types.

Arc Light Distribution.

Series and parallel, alternating and direct currents.

Switchboards and accessories, wiring and controlling devices.

Arc Light Economics.

Hour light schedules.

Commercial rating, candle power, watts.

Efficiency of arc lighting, effect of grade of carbon.

Distribution of light from open and enclosed alternating and direct current arc lamps.

Cost per lamp per year.

Application of Arc Lighting.

Interior and exterior, factories and mills.

ELECTRIC LIGHTING SYSTEMS AND DISTRIBUTION.

Aerial and underground circuits.

Centres, areas and network of distribution.

Feeder and Main, Central and substation, Transformer and Converter distribution.

Regulation of lighting circuits.

Protection of lines, insulation, lightning arresters, etc.

Accumulators in electric lighting service.

Administrators in electric lighting service.

Protection of lines, regulation, inspection, etc.

Regulation of lighting circuits.

Installation.

Design and construction and operation of distribution.

Centers, areas and network of distribution.

Vertical and underground circuits.

Electric lighting systems and distribution.

Installation and operation of electric lighting.

Installation of electric lighting.

Design and construction.

Current and voltage.

Distribution of electric lighting.

Protection of electric lighting.

Commercial lighting, electric power, etc.

Good lighting systems.

Electric lighting.

Installation and operation of electric lighting.

Centers and network of electric lighting.

Arc Light Distribution.

Single or double carbon types.

Design and construction of electric lighting.

Protection of electric lighting.

Arc Lamp.

Design and construction of electric lighting.

Centers and network of electric lighting.

Electric lighting.

Design and construction of electric lighting.

Arc Lamp.

Arc Lamp.

Design and construction of electric lighting.

Electric lighting.

Arc Lamp.

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INCANDESCENT Lamps.

Inspection, selection and testing.

- (1) Examine filament in good light for color, regularity or form, examine globe for regularity of shape, uniformity of size, etc.
- (2) Examine conditions of vacuum by means induction coil.
- (3) Examine filament at half normal voltage for "spots".
- (4) Measure candle power and efficiency in horizontal plane at normal voltage.
- (5) Plot target diagram and determine per cent of lamps *falling* within *target* ~~torque~~ *thickness*.
- (6) Life test. Run lamps at normal voltage, taking readings every 25 hr. per the first 100 hr. and then every 100 hr. Determine time when candle power falls to 80% of its ratio value.
- (7) Filament must be of uniform size, regular form and of a steel gray color. Black or smoky spots show poor flashing. Globes should be of uniform size and shape and not too small, small globes means usually a short life.
- (2) Holding globe of lamp in right hand touch base to plate attached to one terminal of induction coil, grasping at the same time the terminal lamp in left hand. If lamp glows the vacuum is poor. When no light is seen or only a slight flash at base of lamp vacuum is good. Coil should be giving a $3/8$ " spark.
- (3) When a lamp is used at half normal voltage, then or weak spots in filament coils glow brighter than the rest of filament.
- (4) Place lamp in revolving holder and measure *Candle* ~~power~~ ^{Added} and watts at normal voltage. Only lamps of the same rated efficiency and candle power should be compared. Spot off on target diagram values of candle power and watts. Allow three watts variation each way cut one half candles variation each way. Take watts as base and candle power as ordinates.

CIRCUITS AND WINDINGS.

(Revised abstract from "Practical Management of Dynamos and Motors" by Crocker & Wheeler.

The Various Kinds of Circuits on which motors and dynamos are commonly used, and the best type of machine in each case, are as follows:

Direct Current, Constant Potential.

(Circuits on which potential or voltage is kept constant; machines, lamps, etc., being run in parallel).

Circuits intended for	Potential, in volts	Dynamo should be	Motor should be
Electrometallurgy	1 to 150 volts	Shunt Wound.	Not used.
Incandescent lighting	{ 110 or 220 (2-wire sys.) 220 (3-wire sys.) }	Shunt or compound wound.	Shunt, for constant speed. Series or compound, for variable speed.
Electric railway Electric Power	{ 500 volts }	Shunt or compound wound.	Series, for railway. Shunt, for stationary.

Direct, Constant Current.

(Circuits on which current or amperes are kept constant; machines, lamps, etc., being run in series.)

Circuits intended for	Current in Amperes	Dynamo should be	Motor should be
Arc-lighting Power circuits	{ 6.0 9.5 }	Series wound with current regulator	Series wound with speed-regulator.

Alternating Current, Single Phase.
(Almost always constant potential).

Circuits intended for	Potential in volts		Dynamos should be	Motor should be
Incandescent lighting	Primary	Secondary	Separately excited. Also sometimes composite wound.	Specially designed; or induction motors with starting devices.
Arc-lighting (sometimes con-curr)	{ 1100 or 2200 }	{ 55 or 110 or 220 110 or 220 }		
Electric Power.				

Alternating Current, Polyphase.
(Constant potential, two or three phase currents.)

Circuits intended for	Potential in volts		Dynamo should be	Motor is
	On the line	At the motor		
Power transmission.	5000 to 60000. At the generation for 440 2-phase 550 3-phase	110-220 440, 550 Induction. 550-10000	Separately excited sometimes composite wound.	Synchronous or induction with starting devices.
	1100-11000			

Remarks.

Kinds of Circuits. There are really only five classes of electric circuits in very general use.

1. Electrometallurgical Circuits, - potential is usually very low, 3 to 6 volts for electroplating. In electrolytic refining of copper voltage is sometimes about 100 where there are a large number of vats in series. On such low-voltage circuits the current is usually great, being often several thousand amperes. The dynamos should be regulated by means of a rheostat in the field-circuit.

2. Low (Constant) Potential Direct Current Circuits for light and power are either two wire or three wire. On the former the potential is kept constant between 110 and 125 volts, the current being about one-half ampere per 16 candle-power. On the latter incandescent lamp, and about 8 amperes per horse-power or motors in operation. (A standard of 80 volts is adopted in the navy).

The voltage on the three-wire system is between 220 and 250 volts, and the current one half for same power as in two wire system. The two-wire system is almost universally used for light and power distribution, when the distance of the lamps or motors from the dynamos is not more than one-quarter to one-half mile. The three-wire system is employed where the average distance is greater, but not more than one to two miles.

Shunt or compound wound dynamos, generating 115 to 125 volts are used on either the two- or three-wire systems, two dynamos being run in series in the latter case. A single dynamo or a pair of dynamos must be used in small plants, and a dozen or more in large plants. It is always well to have one or more reserve machines.

Motors for the two-wire system should be plain shunt or compound wound, for 115 to 125 volts (5 or 10 volts being allowed for loss in the line) and for the three-wire they should be wound for 230 to 240 volts. Series-wound motors are sometimes used where there is no danger of the load being taken off (by the breaking of the belt, for example) which might allow them to race, and destroy themselves. Compound-wound motors are adapted to work at variable speeds, and they have the advantage that the shunt portions of their field-winding prevents them from racing.

Department of Electrical Engineering.
University of Illinois.

3. Electric Railway Circuits at a nominally constant potential of 500 volts, varying in practice between 450 and 600 volts. The average current is about 15 to 25 amperes per car at normal load. Stationary motors often supplied with current from electric-railway circuits. They should be shunt wound or "overwound series" for 500 volts nominal, but capable of standing at least 550, and should be particularly well made and insulated.

4. Series Arc-Lighting Circuits are usually run at a constant current of about 10 amperes, the potential being about 50 volts per lamp on 10 ampere circuits. The total voltage is usually 2000 or 3000, 40 or 60 lamps being connected in series. System used for arc-lighting where lamps are much scattered, length of circuits sometimes as great as 10 or 15 miles. Arc-lamps often on low-constant potential circuits, placed in parallel.

5. Alternating-current Circuits generally adopted for incandescent lighting, where the distance exceeds one mile, where the low-tension system is not applicable. The great advantage is that it can be transformed into a current of higher or lower pressure by a simple transformer or into direct current by means of a synchronous (rotary) converter.

Motors, dynamos, transformers, and converters for one, two- and three-phase alternating currents, are quite satisfactory machines; at present the necessary circuits are being widely introduced especially the two and three-phase systems. While the purpose to which these poly-phase currents are particularly applicable is the long-distance transmission of power. Many such installations have been placed in factories, mills, and industrial works.

Amp res required to Give Diffrent Powers, on the Various Constant-Potential Circuits, Allowing for the Efficiency of the Ordinary Motor.

Horse-power of Motor.	Efficiency of Motor.	Electrical H.P. Required	Ampere	On 3-volt Battery Circuit	On 75-volt cir-cuit.	On 110-volt Cir-volt cuit.	On 220-volt Cir-volt cuit.	On 500-volt Cir-volt cuit.
1/16	40%	.16	14	1.6	1.1	.53	.23	
1/8	55	.23	21	2.2	1.5	.76	.34	
1/6	60	.28	26	2.8	1.9	.95	.41	
1/4	62	.40	38	4.0	2.7	1.4	.60	
1/2	66	.76	71	7.5	5.1	2.6	1.13	
1	72	1.4	130	13.8	9.4	4.7	2.07	
2	75	2.7		26.6	18.1	9.1	3.90	
3	78	3.8		38.2	26.	13.0	5.73	
4	79	5.0		50.3	34.3	17.2	7.55	
5	80	6.2		62.2	42.4	21.2	9.33	
7-1/2	82	9.1		90.9	62	31.0	13.6	
10	84	12.		118.	80.7	40.4	17.8	
15	88	17.6		176	120.	60.	26.3	
20	86	23.		231	158	79.	34.7	
25	88	28		283	193	96.	42.4	
30	88	34		339	231	116	50.7	
35	89	40.		391	266.	133.	59.	
40	89	45		447	305	153	67.	
50	90	55.5		553	377	188	83.	
75	90	83		828	565	283	124.	
100	90	111.		1107.	754.	377	166.	
From "Practical Management of Dynamos and Motors" by C. F. W.								
One horse power = 746 watts.								
Efficiency of dynamo = Electrical output (watts).								
Efficiency of motor = Mechanical input (watts).								
Common. efficiency of motor = Mechanical output (watts).								
Electrical input (watts).								

- 1.-Conductors: wires, cables; tables, calculations; specifications; sag.
- 2.-Insulators: glass, shellac, porcelain, oils, paper, marble, etc.

II.-CLASSIFICATION OF DISTRIBUTING SYSTEMS.

- 1.-As to kind of electrical supply: direct and alternating current.
- 2.-Constant current(series); constant potential (parallel); combinations.
- 3.-As to location: overhead, underground and submarine circuits.
- 4.-As to use: telegraphy, telephony, lighting, power and traction.

III.-ECONOMICS OF ELECTRIC DISTRIBUTION.

- 1.-Two-wire vs. three-wire, for direct or alternating current.
- 2.-Two-phase alternating current: three-wire vs. four-wire systems.
- 3.-Three-phase alternating current: three-wire vs. four-wire systems.
- 4.-The monocyclic system of distribution.

IV.-WIRING CALCULATIONS.

- 1.-General considerations entering into calculations of wiring.
- 2.-Allowances for: drop, heating effect (temperature rise), capacity.
- 3.-Influence of self-induction and mutual induction, A.C. circuits.

V.-CENTRAL AND SUBSTATION DISTRIBUTING POINTS.

- 1.-Electrical centre of gravity for locating all supply centres.
- 2.-Distributing centres or feeding points: voltage and loads.
- 3.-Sub-stations: voltage and character of loads.
- 4.-The central station or generating plant: voltage and loads.

VI.-FEEDERS AND FEEDING/- Direct Systems.

- 1.-At end of conductors: cylindrical, tapering, parallel, anti-parallel.
- 2.-Central and distributed feeding.

VII.-INDIRECT FEEDING AT DISTRIBUTING CENTRES.

- 1.-Direct current: accumulators, boosters, motor-generators.
- 2.-Alt. Cur.: transformers for constant potential or current; phase.
- 3.-Converter distribution; synchronous converters, inverted rotaries.
- 4.-Rectifier distribution, A.C. input to D.C. output.

VIII.-DISTRIBUTING CIRCUITS.

- 1.-As to location: exterior and interior wiring.
- 2.-As to extensions: linear, branched and network systems.
- 3.-Interior wiring: open and concealed; tree, closet and loop systems.

IX.-INSTALLATION OF ELECTRICAL CIRCUITS.

- 1.-Rules and regulations. National Electric Code.
- 2.-Construction: mechanical and electric details.
- 3.-Accessories: switchboards, protective devices, etc.

X.-INSPECTION AND TESTING ELECTRICAL CIRCUITS.

See Electrical Engineering Laboratory schedules, No. 0.2 and 61.
Plate 4, on comparative methods and insulation resistance.

XI.-Regulation of Electrical Distribution.

- 1.-Faulty working of distributing systems and remedies.
- 2.-Regulation of direct-current systems: at generator, on feeders.
- 3.-Regulation of Alt. Cur. systems: constant current or potential.
- 4.-Auto-transformers, stage regulators and dimmers.
- 5.-Types of Alt. Cur. regulators and reactive coils used as such.

XII.-PROTECTION OF DISTRIBUTING CIRCUITS.

- 1.-From mechanical injuries: cable sheathing, armoured conduit, etc.
- 2.-From electrical interruptions: fuses and circuit breakers.
- 3.-From lightning: lightning arresters for various circuits and service.
- 4.-From grounds: ground detectors, earthing and grounding devices.
- 5.-From fire hazards and life risks: grounding neutral and secondaries.

XIII.-MAINTENANCE, REPAIRS AND RENEWALS.

- 1.-Ageing effects of various parts of distributing circuits.
- 2.-Provisions against interruptions or hazards due to ageing effects.

Syllabus of Lectures. ELECTRIC TRANSMISSION.

I.-CLASSIFICATIONS OF SYSTEMS.

- 1.-As to kind of service: direct and alternating current; composite system
- 2.-As to constant factors: constant current, constant potential systems.

II.-PROPERTIES OF TRANSMISSION LINES.

- 1.-Resistance: ohmic, inductive, apparent; and virtual resistance.
- 2.-Reactance: inductive reactance (or inductance), due to self induction. capacity reactance (or condensance) due to capacity.
- 3.- Impedance, resultant of ohmic and inductive resistances.
- 4.-Skin effect, reducing effective area of conductor; virtual resistance.
- 5.-Leakage of current due to imperfect insulation of lines.
- 6.-Charging current (wattless) required by capacity of long lines.
- 7.-~~Charging current~~ Resonance, condition permitting rise of E.M.F. at receiver when self-induction and capacity exactly neutralize each other
- 8.-Mutual induction, effect of other and nearby transmission circuits.

III.-ECONOMICS OF TRANSMISSION LINES.

Relative weights of copper required for the various systems.

- 1.-4. Compare subdivisions under "Electric Distribution." III.

- 5.-Losses due to ohmic and reactive drop, skin effect, leakage, charging current, heating of conductors.

IV.-CALCULATION OF TRANSMISSION LINES.

- 1.-Line constants, wire tables, calculations and use of same.
- 2.-General considerations entering into line calculations.

- 3.-Effect on performance through choice of voltage, phase frequency.
- 4.-Allowances for drop, heating and carrying capacity of conductors.

- 5.-Influence of inductance, self and mutual; how minimized.
- 6.-Influence of capacity of transmission line.

- 7.-Character of loads and variations: kind, amount, time; load factor.
- (a) Non-inductive loads; inductive and capacity loads, fixed or variable
- (b) Balanced or unbalanced loads in polyphase systems.

V.-INSULATION OF TRANSMISSION LINES.

- 1.-Construction: mechanical and electrical details; transposition.
- 2.-Accessories, protective devices, etc.

VI.-INSPECTION AND TESTING OF TRANSMISSION LINES.

- 1.-See Electrical Engineering Laboratory schedules, No. 0.2 and 61.
- 2.-Plate 4, on comparative methods and insulation resistance.
- 3.-Measurement of properties of transmission lines: resistance, leakage, charging current, drop, resonant rise, power factor and efficiency.

VII.-REGULATION OF ELECTRIC TRANSMISSION.

- 1.-Faulty working of transmission lines and remedies.

- 2.-Regulation of direct current systems, chiefly constant potential.

- (a) Compensation for line drop, by condensance or synchronous motors.
- (b) Neutralization to obtain unity power factor:

- (i) Neutralization of wattless currents, in parallel, as by induction and over-excited synchronous motors.

- (ii) Neutralization of reactances in series with line.

VIII.-PROTECTION OF TRANSMISSION LINES.

- 1.-From electrical interruptions: fuses, circuit breakers.
- 2.-From lightning: arresters for various circuits and services.
- 3.-Grounds, earth discharging and grounding devices.
- 4.-Leakage and faulty insulation troubles.

IX.-DEVELOPMENT OF ELECTRIC TRANSMISSION.

- 1.-From hydraulic generating plants.
- 2.-From steam generating plants.
- 3.-Some examples, from 3 to 150 miles, 10,000 to 60,000 volts, polyphase.

I.--GENERAL CONSIDERATIONS AND REQUIREMENTS.

1.--Electric transmission in manufacturing work, a means to an end:

- (a) Centralized power generation for light and manufacturing.
- (b) Subdivision of transmission system and motive power.
- (c) Execution of work, irrespective of its location.
- (d) Maximum efficiency of workman and labor involved; piece work.
- (e) Intensified production, at best speeds and power limit of machine, improved quality and maximum output, reduced cost.

2.--Sanitary considerations: healthful; clean free from dirt, dust and dripping oil; affords accommodations and facilities for proper lighting and ventilation; reduces sick list to minimum; conduces to shop order and discipline, quietness and cheerfulness of workmen.

3.--Disciplinary value: most economic use of workman's time, quick handling of labor and material, maximum efficiency of labor.

4.--Flexibility of systems, accessibility of all parts, adaptability to various uses, portability of tools.

5.--Reliability of service; freedom from general stoppage, localizing casualties and stopping least machinery from repairs.

II.--APPLICATIONS OF ELECTRICITY TO MANUFACTURING WORK.

1.--Development of the Electric Drive, and method of driving.

(a) Fixed machines or tools:

INDIVIDUAL or direct-connected motor driving:

Motor is directly applied to the work in hand.

Workman has most perfect control of all factors entering entering into the economics of production.

Direct and independent control of wide range of speeds, earlier limited by speed of line shafting.

Increased efficiency of machine, reduced time and cost of labor, maximum economy in application of power.

Choice of, depends upon power required, time the motor is in use and value of the product.

Usually adopted where over two or three horse power is required or machine is in use only part of time, or

requires wide variations in speed and power for maximum output, independent of first cost.

Constructive details and design of machine not usually altered; secondary speed changes obtained by usual change of gear and mechanism; in special cases, of large tools, speed changes sometimes provided for by use of a special variable speed motor.

GROUP driving:

Few large motors, driving sections of shafting of the most economical length.

Adopted for driving a number of quite small machines, with no special requirements in speed, or power.

In use for separate floors and detached buildings.

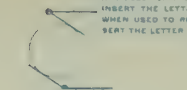
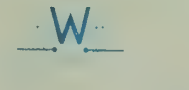
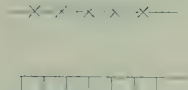
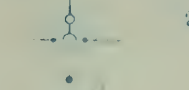
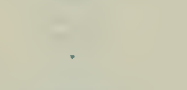
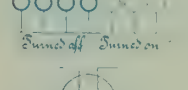
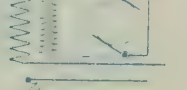
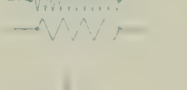
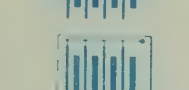
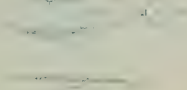
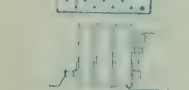
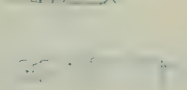
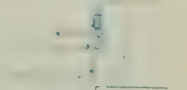
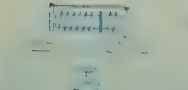
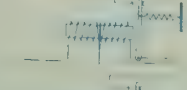
(b) Portable tools, and appliances, for production and conveying operations, forming part of transmission system, facilitating economic production by taking tool to the work.

(c) Consideration of motions and movements:

Rotary or reciprocating, intermittent or continuous, uniform or variable, reversible or otherwise.

Syllabus of Lectures. Factory Transmission.

NOTE: WHEN ANY OF THESE DIAGRAMS ARE USED FOR A DYNAMO OR GENERATOR INSERT THE LETTER G IN THE DIAGRAM WHEN USED TO REPRESENT A MOTOR INSERT THE LETTER M

	Crossing Wires		Ammeter		Dynamo or Motor		Resistance
	Joined Wires		Voltmeter		Alternator Generator or Motor		Capacitor
	Ground		Wattmeter		Series Wound Dynamo or Motor		Autostat
	Arc Lamps		Relay Indicator or Galvanometer		Shunt Wound Dynamo or Motor		Circuit Breaker
	Incandescent Circuit		Switch		Compound Wound Dynamo or Motor		Telegraph Line
	Incandescent Lamp		Knife Switch - Closed		Six Phase Dynamo or Motor (Star Connection)		Telegraph Sounder
	Condenser		Knife Switch - Open		Six Phase Dynamo or Motor (Triangular Connection)		Relay
	Telephone Fork		Motor Generator		Bell		Variable Resistance
	Hand Dynamo		Battery		Solano Dynamo		Spring Jack
	Head Dynamo		Storage Cell		Dynamo		Relay
	Transmitter		Magneto Generator		Differential Relay		Single Pole Circuit Breaker
	Communicator or Drop		Constantly Driven Magneto		Solano Relay		Double Pole Circuit Breaker
	Self restoring Commutator or Drop		Shunt Selective Generator		Lighting Dynamo		
	Induction and Dropping Key		Current and EMF Curves (Alternating)				

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Symbols for Physical Quantities and Abbreviations for Units.

Recommended by the Committee on Notation of the International Electrical Congress of 1893, with additions of the International Electrical Congress of 1900.

PHYSICAL QUANTITIES.	SYMBOLS.	DEFINING EQUATIONS.	DIMENSIONS OF THE PHYSICAL QUANTITIES.	NAMES OF THE C. G. S. UNITS.	ABBREVIATIONS OF THE NAMES OF THE C. G. S. UNITS.	PRACTICAL UNITS.	ABBREVIATIONS OF THE PRACTICAL UNITS.
Fundamental.							
LENGTH.....	L, l		L	Centimetre.	cm	Metre.	m
MASS.....	M, m		M	Mass of one gramme.	g	Mass of a kilogramme.	kg
TIME.....	T, t		T	Second.	s	Minute; hour.	m; h
Geometric.							
SURFACE.....	S, s	$S = LL$	L^2	Square centimetre.	cm ²	Square metre.	m ²
VOLUME.....	V, v	$V = LLL$	L^3	Cubic centimetre.	cm ³	Cubic metre.	m ³
Mechanical.							
ANGLE.....	α, β	$\alpha = \text{arc radius}$	A number.	Radian.		Degree; minute; second; grade.	m : s
VELOCITY.....	v	$v = \frac{L}{T}$	$L T^{-1}$	Centimetre per second.	cm : s	Metre per second.	m : s
ANGULAR VELOCITY.....	ω	$\omega = \frac{\theta}{T}$	T^{-1}	Radian per second.		Revolutions (turns) per minute.	t : m
ACCELERATION.....	a	$a = \frac{v}{T}$	$L T^{-2}$	Centimetre per second per second.	cm : s ²	Metre per second per second.	m : s ²
FORCE.....	F, f	$F = Ma$	$L M T^{-2}$	Dyne.	dyne	Gramme; kilogramme.	g; kg
WORK.....	W, w	$W = FL$	$L^2 M T^{-2}$	Erg.	erg	Kilogramme.	kgm
POWER.....	P	$P = \frac{W}{T}$	$L^2 M T^{-3}$	Erg per second.	erg : s	Kilogramme per second.	kgm : s
PRESSURE.....	p	$p = \frac{F}{S}$	$L^{-1} M T^{-2}$	Baric.	dyne : cm ²		
MOMENT OF INERTIA.....	K	$K = ML^2$	$L^2 M$	Gramme-mass-centimetre-squared.	g-cm ²		
Magnetic.							
STRENGTH OF POLE.....	m	$F = \frac{m^2}{L^2}$	$L M^{\frac{1}{2}} T^{-1}$	Gauss.		Gauss.	
MAGNETIC MOMENT.....	$\mathfrak{M}$	$\mathfrak{M} = mL$	$L M^{\frac{1}{2}} T^{-1}$	Maxwell.		Maxwell.	
INTENSITY OF MAGNETIZATION.....	$\mathfrak{J}$	$\mathfrak{J} = \frac{\mathfrak{M}}{V}$	$L^{\frac{1}{2}} M^{\frac{1}{2}} T^{-1}$	Gauss.		"Gauss.	
FIELD INTENSITY.....	$\mathfrak{H}$	$\mathfrak{H} = \frac{F}{L}$	$L^{\frac{1}{2}} M^{\frac{1}{2}} T^{-1}$				
FLUX OF (MAGNETIC) FORCE.....	ϕ	$\phi = \mathfrak{H} S$	$L M^{\frac{1}{2}} T^{-1}$				
MAGNETIC INDUCTION.....	$\mathfrak{B}$	$\mathfrak{B} = \mu \mathfrak{H}$	$L^{\frac{1}{2}} M^{\frac{1}{2}} T^{-1}$				
MAGNETIZING FORCE.....	$\mathfrak{H}$	$\mathfrak{H} = \frac{4\pi}{L} \mathfrak{M}$	$L^{\frac{1}{2}} M^{\frac{1}{2}} T^{-1}$				
MAGNETOMOTIVE FORCE.....	$\mathfrak{E}$	$\mathfrak{E} = 4\pi \mathfrak{M} L$	$L^{\frac{1}{2}} M^{\frac{1}{2}} T^{-1}$	Gilbert.*		1 Gilbert* = 0.7958 ampere-turns	a-t
RELUCTANCE (MAGNETIC RESISTANCE).....	$\mathfrak{R}$	$\mathfrak{R} = \frac{L}{S}$	L^{-1}	Oersted.*			
(MAGNETIC) PERMEABILITY.....	μ	$\mu = \frac{\mathfrak{B}}{\mathfrak{H}}$	A number.				
(MAGNETIC) SUSCEPTIBILITY.....	κ	$\kappa = \frac{\mathfrak{J}}{\mathfrak{H}}$	A number.				
RELUCTIVITY (SPECIFIC MAGNETIC RESISTANCE).....	ν	$\nu = \frac{1}{\mu}$	A number.				
Electromagnetic.							
RESISTANCE.....	R, r	$R = \frac{E}{I}$	$L T^{-1}$			Ohm.	ohm
ELECTROMOTIVE FORCE.....	E, e	$E = RI$	$L M^{\frac{1}{2}} T^{-2}$			Volt.	v
DIFFERENCE OF POTENTIAL.....	U, u	$U = RI$	$L M^{\frac{1}{2}} T^{-2}$			Volt.	v
INTENSITY OF CURRENT.....	I, i	$I = \frac{E}{R}$	$L^{\frac{1}{2}} M^{\frac{1}{2}} T^{-1}$			Ampere.	
QUANTITY OF ELECTRICITY.....	Q, q	$Q = IT$	$L M^{\frac{1}{2}}$			Coulomb; ampere-hour.	c; a-h
CAPACITY.....	C, c	$C = \frac{Q}{E}$	$L^{-1} T^2$			Farad.	f
ELECTRIC ENERGY.....	W, w	$W = EI T$	$L^2 M T^{-2}$			Joule; watt-hour.	J; w-h
ELECTRIC POWER.....	P	$P = EI$	$L^2 M T^{-3}$			Watt; kilowatt.	w; kw
RESISTIVITY (SPECIFIC RESISTANCE).....	ρ	$\rho = \frac{RS}{L}$	$L^2 T^{-1}$			Ohm-centimetre.	ohm-cm
CONDUCTANCE.....	G, g	$G = \frac{1}{R}$	$L^{-1} T$			Mho.	mho
CONDUCTIVITY (SPECIFIC CONDUCTANCE).....	γ	$\gamma = \frac{1}{\rho}$	$L^{-1} T$				
COEFFICIENT OF INDUCTION (INDUCTANCE).....	L, l	$L = \frac{\phi}{I}$	L			Henry.	H
FREQUENCY.....	n		Numeric.			~	
ADMITTANCE.....	Y	$Y = \frac{1}{Z}$	$L^{-1} T^{-1}$			Mho.	mho
IMPEDANCE.....	Z	$Z = \frac{1}{Y}$	$L T^{-1}$			Ohm.	ohm
REACTANCE.....	X	$X = 2\pi nL$	$L T^{-1}$			Ohm.	ohm
SUSCEPTANCE.....	B	$B = \frac{1}{X} = \frac{1}{2\pi nL}$	$L^{-1} T^{-1}$			Mho.	mho

* Name provisionally adopted by the American Institute of Electrical Engineers.

† The International Bureau of Weights and Measures has established an important distinction in the notation of time, according as it refers to the *epoch* (date or time of day) or the *duration* of a phenomenon. In the former case the reference letters *h*, *m*, *s*, and *ms* are used, and in the latter they are on the same line with the numbers; for instance, an experiment began at 15^h 40^m 45^s, and ended at 4^h 31^m 35^s. It is recommended that the latter notation should be used.

‡ *n* is the number of turns, and *L* the length of the solenoid generating the magnetizing force. †† Plane Vector Quantity.

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Fig. 1

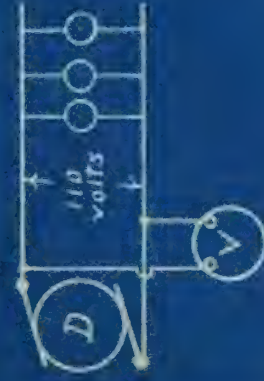


Fig. 2

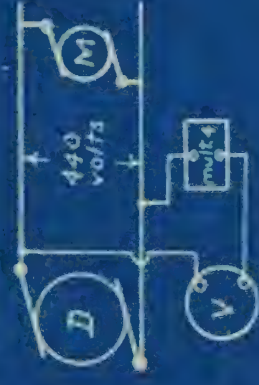


Fig. 3



Voltmeter on 110-volt circuit. Same voltmeter with multiplier for 440-volt connections.

Fig. 4

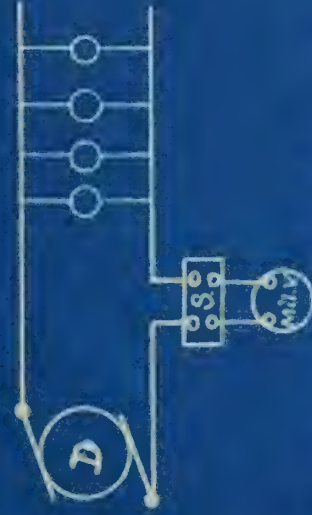
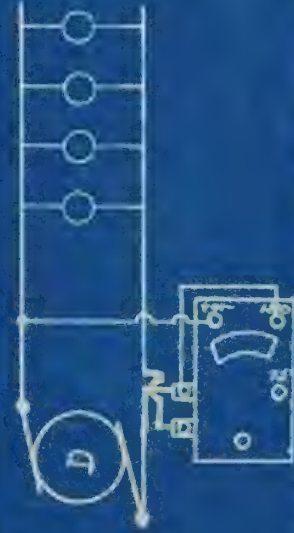


Fig. 5



Standard Connections for Indicating Wattmeter.

Fig. 6



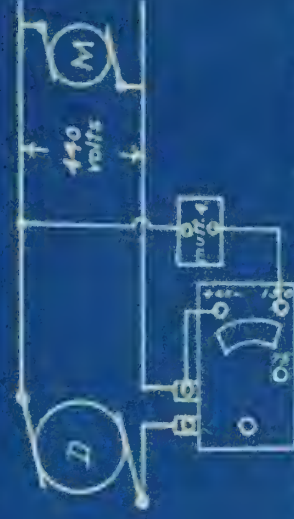
Indicating Wattmeter Connections. Short pressure wire to other terminal.

Fig. 8



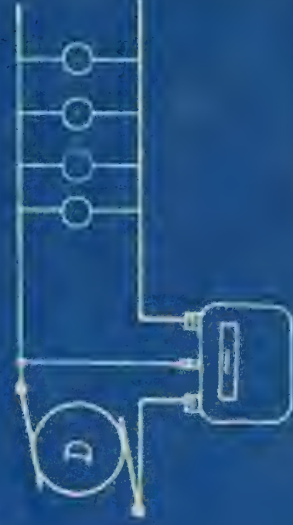
Wattmeter short-circuited for heavy starting currents. e.g. Ind. motor.

Fig. 7



Indicating Wattmeter with multiplier. Neglect to place Mult. in circuit will result in burn out of instrument.

Fig. 9



Recording Wattmeter Connections.

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MEASUREMENT OF LOW RESISTANCES, ARMATURES, TRANSFORMER SECONDARIES, ETC.



Fig. 1.

A₁ - Resistance to be measured, inserted in series in external circuit of 110 volts from dynamo.



Fig. 2.

A₂ - Resistance to be measured in series with suitable battery current.

B. Measurement of High Resistance, - Shunt Fields, Transformer Primaries, etc.



Fig. 3.

Simple 110 volt circuit may be used.

II. MEASUREMENT OF RESISTANCE BY COMPARATIVE METHODS.

A, Meas'd by V_m alone
Compared with known Res.

Fig. 4.



$$R = r \frac{V}{V'}$$

where R = unknown res.

r = known res.

V = V_m reading,

V_m in shunt

V' = V_m reading,

V_m in shunt

with R.

B, Measured by V_m alone.

Fig. 5.



$$R = r \left(\frac{V - V_1}{V_1} \right)$$

where R = unknown res.

r = res V_m .

V = V_m reading

V_1 = V_m reading

switch closed.

V_1 = V_m reading

switch open.

C. Meas't of Insulation resistance.

Fig. 6.



$$R = r \left(\frac{V - V'}{V'} \right)$$

where R = res. insulation.

r = res V_m .

V = diff. in potential

betw. two sides

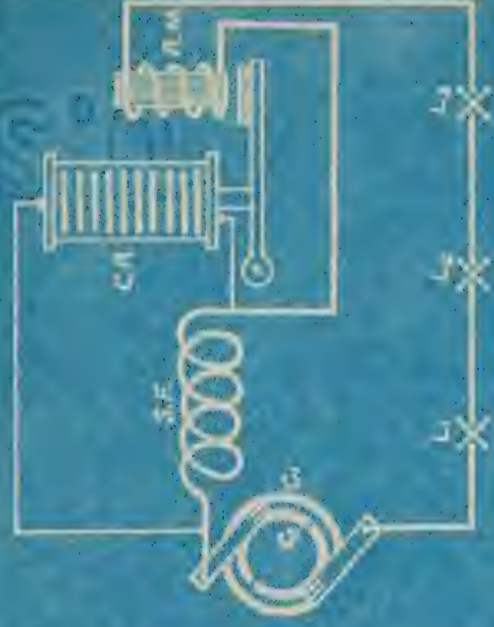
of line.

V' = diff. in pot. betw.

either side of line

and ground.

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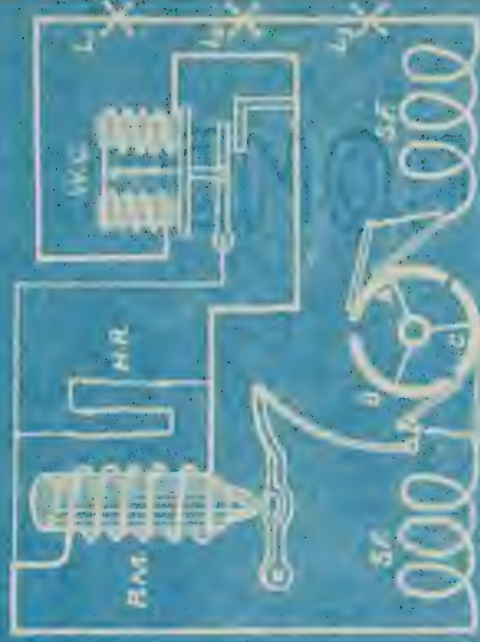


Control by shunting portion of current from field coils when lower EMF is required.

Armature Connections and Regulating Mechanism for Brush Arc Light Machine.

C₁, C₂. First and Second Commutators.
SF. Series Field.
CR. Carbon Resistance.
RM. Regulating Magnet.

L₁, L₂, L₃. Lamps.



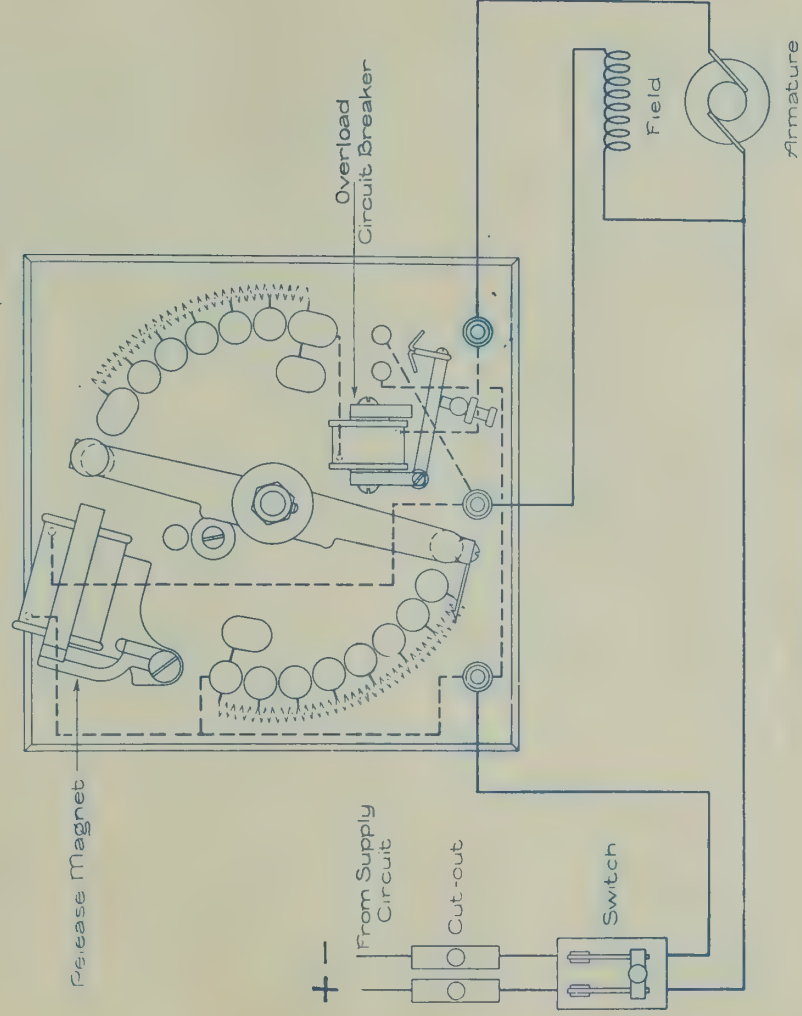
Control by shunting portion of current from field coils when lower EMF is required.

Armature Connections and Regulating Mechanism for Thomson-Houston Arc Machine.

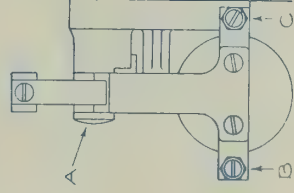
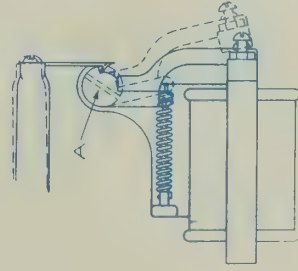
RM. Regulating Magnet.
CR. Carbon Resistance.
SF. Series Field.
L₁, L₂, L₃. Lamps.

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CONNECTIONS OF STARTING RHEOSTAT FOR SHUNT WOUND MOTORS WITH AUTOMATIC RELEASE IN FIELD CIRCUIT OF MOTOR AND OVERLOAD CIRCUIT BREAKER



Details of Release Magnet



General Electric Co.

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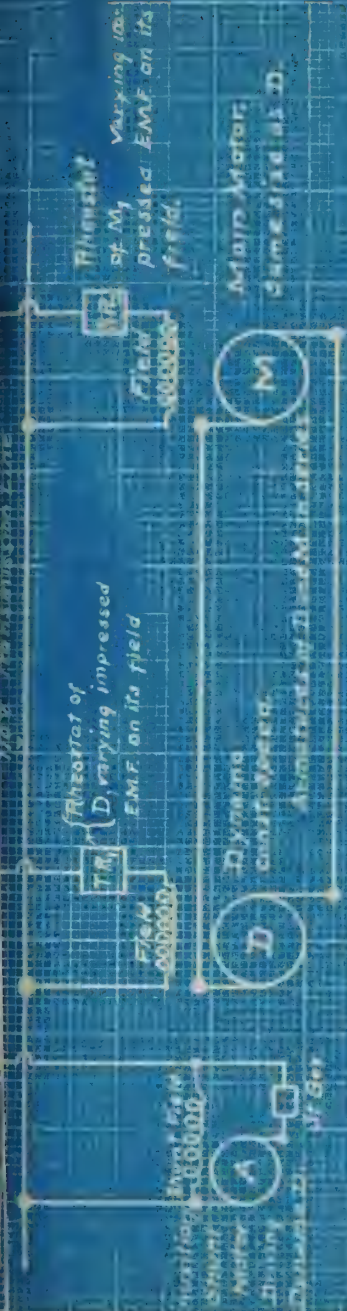


Fig. E. Connections for operating Ward Leonard System of Motor Control.

Fig. E.

Speed constant

Torque $\propto$ Arm. current

$$\text{Torque} = \frac{SNC_a}{5.5 \times 10^3}$$

Fig. F.

Torque constant

Speed $\propto$ EMF

$$\text{EMF} = \frac{2NV}{10^8}$$

Volts at brushes

ca. 1000V in generator
internal voltage, 1000V in motor

Torque, lb. of ft. per unit

Fig. F.

Variable torque, constant speed

Variable speed, constant torque

Ward Leonard efficiencies, for various conditions.

Percent full load output

Fig. F.

W.L. motorizing

Maximum efficiency

Efficiency based on motor

Efficiency based on line

Efficiency based on total current

Efficiency based on system

Efficiency based on variable torque

Percent full load output

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Fig. 2



MAGNETIZATION CURVES GENERATOR

Fig. 3



Ordinates of T Curve = Algebraic sum of ordinates of A and M Curves, in and out of phase

Magnetization Curves MOTOR

Fig. 4



Ordinate of T Curve = $\Sigma (a \cos \alpha)$

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Characteristic Curves Sump Dynamo

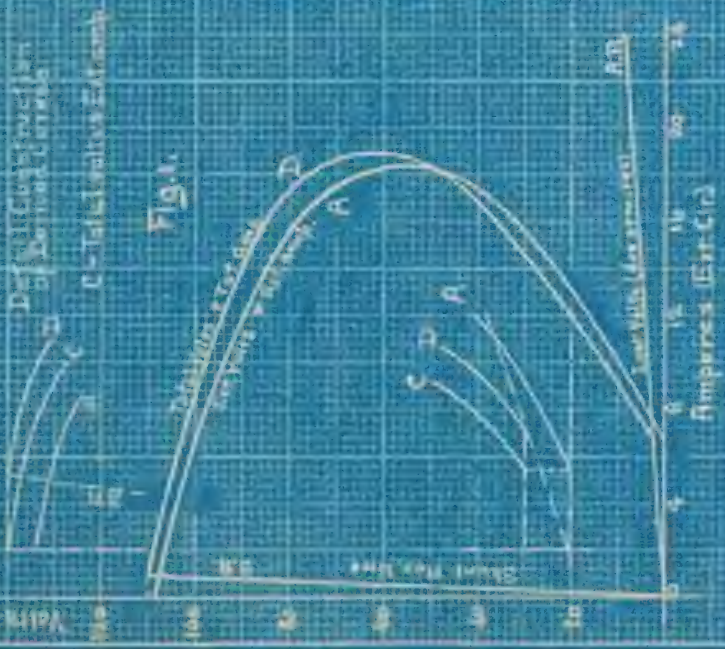


Fig. 1

Characteristic Curves Sump Dynamo

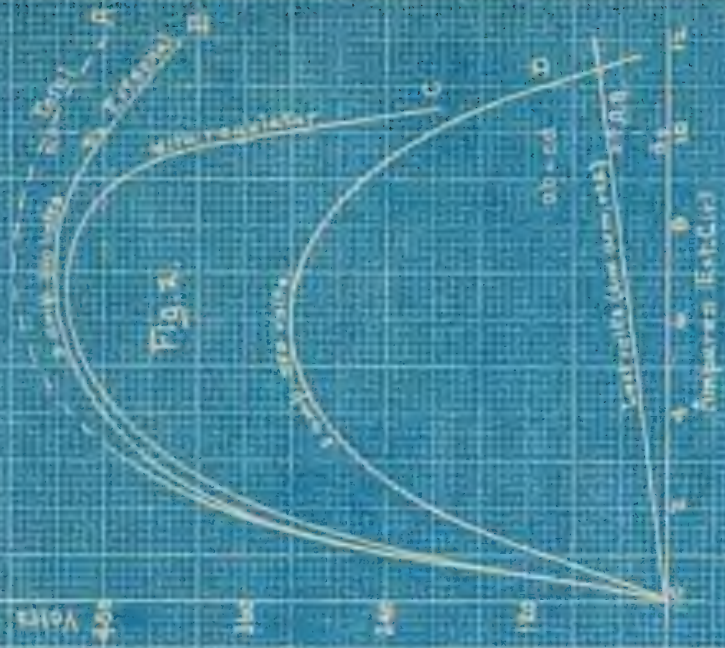


Fig. 2

External Characteristic Curves Compound Dynamo

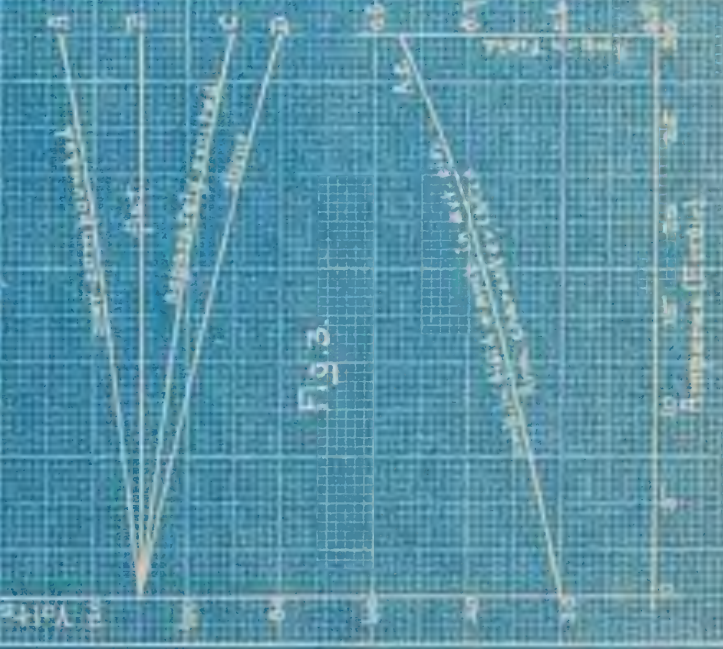


Fig. 3

External Characteristic Curves T.H. Thermobol Sump Dynamo

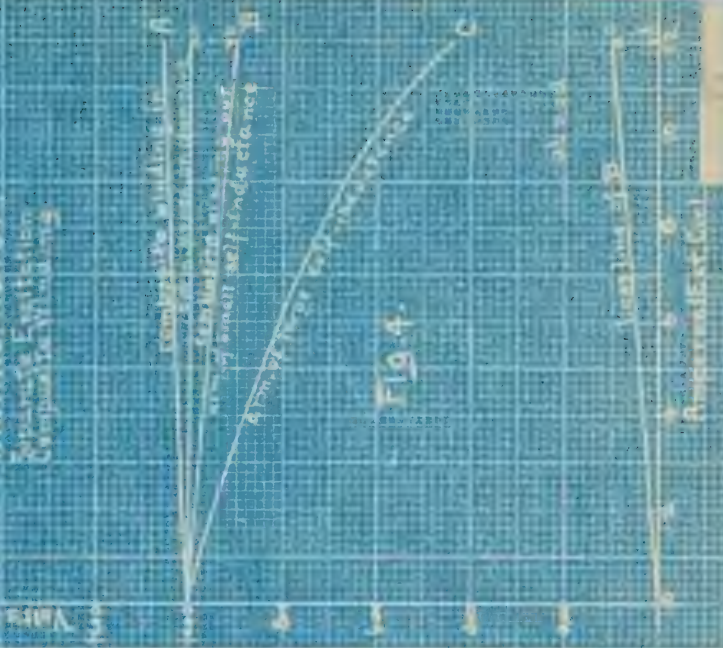
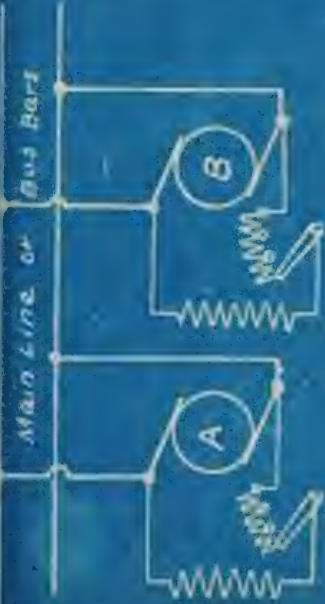


Fig. 4

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Shunt machines in Parallel



Shunt machines in Series.
(b) fields independent.
Dotted connections for 3-wire system.



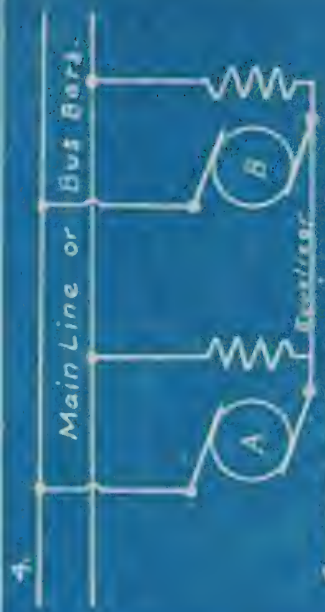
Series machines in Parallel.
Mutual Excitation.



Compound machines in Series.
Two-wire system.



Shunt machines in Series.
(a) Fields in series.



Equalizer divides load proportionately
between the two machines.
Series machines in Parallel.
With equalizer.

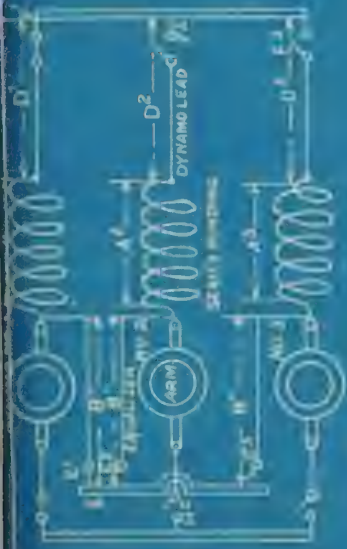


Compound machines in Parallel.



Compound machines in Series.
Three-wire system.

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EQUALIZER AT SWITCH BOARD



EQUALIZER AT DYNAMO

THE CIRCUITS THAT AFFECT THE MUTUAL COMPOUNDING OF DYNAMOS WORKING IN MULTIPLE ARE, THE SERIES WINDING A', EQUALIZERS, B', AND DYNAMO LEADS, C', FIG. 1, SHEET 3. TO OPERATE ANY COMPOUND DYNAMOS IN MULTIPLE, SO THAT THEY WILL CARRY VARYING LOADS IN PROPORTION TO THEIR OUTPUTS, THE FOLLOWING RULES MUST BE OBSERVED: THAT THE RESISTANCE A', B', AND D' CONSTITUTE THOSE RESISTANCES WHICH ARE INVOLVED IN PROPERLY EQUALIZING THE DYNAMOS, AND THAT THE CONDUCTIVITY OF THE EQUALIZER CIRCUITS FOR EACH DYNAMO MUST BEAR THE SAME RATIO TO THE CONDUCTIVITY OF ALL EQUALIZING CIRCUITS IN MULTIPLE, AS THE OUTPUT OF EACH DYNAMO BEARS TO THE TOTAL OUTPUT OF ALL DYNAMOS.

FIRST, CONSIDER EQUALIZING DYNAMOS OF THE SAME DESIGN AND OUTPUT; THE USUAL METHOD OF CONNECTING IS SHOWN IN FIG. 1. TO MAKE THESE DYNAMOS WORK PROPERLY TOGETHER, IT IS NECESSARY THAT THE RESISTANCE BETWEEN EQUALIZER BUS, E, AND BUS, F, BE THE SAME FOR ALL DYNAMOS, AND THAT BUS, F, SHOULD NOT HAVE ANY APPRECIABLE RESISTANCE, OR THE EQUALIZERS MAY BE DIRECTLY TIED TOGETHER, AS IN FIG. 2. IF DYNAMO NO. 1 IS ON THE BUS, AND IT IS REQUIRED TO THROW DYNAMO NO. 2 IN PARALLEL WITH IT, EQUALIZER SWITCH, Z², IS THROWN; THIS HAS NO EFFECT UNTIL SWITCH, Y², IS THROWN; THEN THE CURRENT FLOWS THROUGH THE SERIES COIL OF NO. 2, AND IS DIVERTED FROM THE SERIES WINDING OF THE OPERATING DYNAMO; THE AMOUNT OF CURRENT THUS DIVERTED DEPENDS ON THE RATIO OF THE TWO PARALLEL CIRCUITS.

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WHEN DYNAMO NO. 2 IS BROUGHT UP TO SPEED AND BUS VOLTAGE, SWITCH N² IS THROWN IN, AND THE CURRENT GRADUALLY FADES OUT OF THE EQUALIZER CONNECTION, AS DYNAMO NO. 2 TAKES ITS PROPORTION OF THE LOAD, THE EQUALIZER CONNECTION HAS THE FUNCTION OF MAINTAINING THE SAME VOLTAGE AT THE TERMINALS OF THE TWO MACHINES, AND THERE WILL BE NO TENDENCY TO CROSS-COMPOUND.

WHERE SIMILAR DYNAMOS ARE LOCATED AT DIFFERENT DISTANCES FROM THE SWITCHBOARD, THEIR EQUALIZING CONNECTIONS MUST BE ALL EQUAL IN RESISTANCE TO THE GENERATOR WHICH HAS THE LONGEST LEADS, IF THE SAME CURRENT DENSITY HAS BEEN FIGURED ON ALL THE LEADS. IN EQUALIZING DYNAMOS OF DIFFERENT DESIGNS AND OUTPUTS, THE SAME RELATION OF EQUALIZING CIRCUITS MUST EXIST BETWEEN THE DIFFERENT DYNAMOS, AS IN SIMILAR DYNAMOS, EXCEPT THAT THE RESISTANCE OF THE DIFFERENT EQUALIZER CIRCUITS DECREASES AS THE OUTPUT OF THE DYNAMO INCREASES. IN OTHER WORDS, THE DROP BETWEEN THE EQUALIZER BUS-BAR AND SERIES BUS-BAR MUST BE THE SAME FOR ALL UNITS WORKING IN PARALLEL, WHERE FULLY LOADED, OR THE MAXIMUM CURRENT DELIVERED BY UNIT, MULTIPLIED BY THE RESISTANCE OF ITS EQUALIZER CIRCUIT, MUST BE EQUAL TO A CONSTANT, WHICH IS $CR = E$.

TWO METHODS OF CONNECTING EQUALIZERS ARE RECOMMENDED; ONE TO TAKE EQUALIZERS BACK TO THE SWITCHBOARD, AND THE OTHER TO EQUALIZE AT THE GENERATORS. THE ONLY ADVANTAGES GAINED BY THE FIRST METHOD IS THAT THE EQUALIZING CONNECTION IS UNDER THE CONTROL OF SWITCHBOARD ATTENDANT, BUT AS THE RESISTANCE OF EQUALIZER LEAD IS INCREASED, THE MACHINES DO NOT TEND TO DIVIDE THE LOAD SO READILY BETWEEN THEMSELVES, AND ACT MORE AS INDEPENDENT MACHINES IN MULTIPLE.

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Table 3.—Dynamoes—Efficiency Formulæ.

(Munro and Jamieson.)

	Series Machine.	Shunt Machine.	Compound Machine (Short Shunt).
Watts lost in armature } Watts lost in magnet coils }	$C_a^2 R_a$ $C_m^2 R_m$	$C_a^2 R_a$ $C_s^2 R_s = E_e^2 \div R_s$	$C_a^2 R_a$ $C_a^2 R_m + C_s^2 R_s$
Lost volts	$C_a R_a$	$C_a R_a$	$C_a R_a + C_e R_m$
Total electrical energy (per sec.)	$E_a C_a = C_a^2 (R_a + R_m + R_e)$	$E_a C_a = C_a^2 \left(R_a + \frac{R_s R_e}{R_e + R_s} \right)$	$E_a C_a = C_a^2 \left(R_a + \frac{R_s (R_m + R_e)}{R_s + R_m + R_e} \right)$
Useful electrical output.	$E_e C_a = C_a^2 R_e$	$E_e C_e = C_e^2 R_e$	$E_e C_e = C_e^2 R_e$
Economic co-efficient	$\frac{E_e}{E_a} = \frac{R_e}{R_a + R_m + R_e}$	$\frac{C_e^2 R_e}{C_e^2 R_e + C_a^2 R_a + C_s^2 R_s}$	$\frac{C_e^2 R_e}{C_e^2 R_e + C_a^2 R_m + C_s^2 R_s}$
Commercial efficiency (per cent.)	$100 \times E_e C_e \div (\text{H.-P.} \times 746)$	$100 \times E_e C_e \div (\text{H.-P.} \times 746)$	$100 \times E_e C_e \div (\text{H.-P.} \times 746)$
	N.B.—Horse-power is converted into watts (so as to compare with electric output of the machine) by multiplying by 746.	* This will be a maximum when R_e is a mean proportional between R_s and R_a .	In well-constructed compound machines the difference between "short shunt" and "long shunt" is very slight, as, R_m , is so small.

The appendix a , refers to armature ; e , to external circuit ; m , to field magnet ; s , to shunt winding.

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Efficiency

Efficiency and Regulation Curves Compound Generator

PERCENT EFFICIENCY

Volts

Regulation

Watts Loss

IR
Armature

IR
Series

IR
Shunt

Iron

Core

Watt

Watts Armature

Proportional Part of Full Load (Output)

Separation of Losses in a Compound Generator

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MOTOR-GENERATOR TESTS.

Machines to be of same type and size, and driven at proper speed by belt or mechanical connection.

In Hopkinson's method the losses in each machine are assumed to be the same, whether operated as dynamo or motor.

In Kapp's method the efficiencies of each machine are assumed to be the same, whether operated as dynamo or motor.



Fig. 1. HOPKINSON'S CIRCULATING (MOTOR-GENERATOR) TEST.

$$\text{Motor Efficiency} = \frac{A_c V_c - \frac{A_i V_i}{2}}{A_c V_c + A_m V_i}; \quad \text{Dynamo Efficiency} = \frac{A_c V_c - \frac{A_i V_i}{2}}{A_c V_c + \frac{A_i V_i}{2} + A_d V_i}.$$



Fig. 2. HOPKINSON'S CIRCULATING (MOTOR-GENERATOR) TEST.

$$\text{Motor Efficiency} = \frac{A_c V_c + \frac{A_i V_i}{2}}{A_c V_c + A_i V_i + A_m V_i}; \quad \text{Dynamo Efficiency} = \frac{A_c V_c}{A_c V_c + \frac{A_i V_i}{2} + A_d V_i}$$



Fig. 3. KAPP'S METHOD OF TESTING EFFICIENCIES.

A_1 = Current when switch is to right; A_2 = Current, switch to left.

Efficiency of combination = $\frac{A_1}{A_2}$; Efficiency of either machine = $\sqrt{\frac{A_1}{A_2}}$.

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POWER MEASUREMENTS OF ALTERNATING CURRENTS.

Fig. 1.

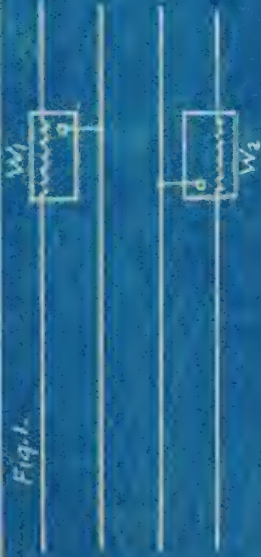


Fig. 2.



2 PHASE, 4 WIRE:- Independent 2 PHASE, 3 WIRE:- Total Power
Measurement of Power of each phase = Sum of Two Readings.
 $P = W_1 + W_2$
In either of above systems, if there is perfect balance, total power =
twice power measured by one wattmeter.

Fig. 3.



Fig. 4.



3 PHASE, Y SYSTEM:- Total Power
= Sum of Readings.

3 PHASE, DELTA SYSTEM:- Total
Power = Sum of Readings.

$$P = W_1 + W_2 + W_3$$

$$P = W_1 + W_2 + W_3$$

In either of above systems, if there is perfect balance, total power =
three times power measured by one wattmeter.

Fig. 5.

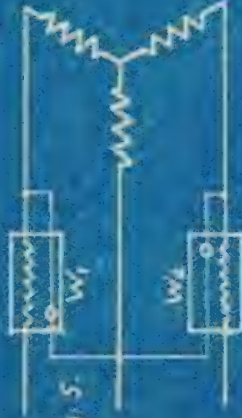


Fig. 6.



In each of above cases of 3-phase systems, Y and Δ , total power = algebraic sum of readings, W_1 and W_2 , independent of balance or lag.

(a) If equivalent lag is less than 60° , or power factor greater than 0.50 then, arithmetical sum of readings = power; $P = W_1 + W_2$.

(b) If equivalent lag is greater than 60° , or power factor less than 0.50 then, arithmetical difference of readings = power; $P = W_1 - W_2$.

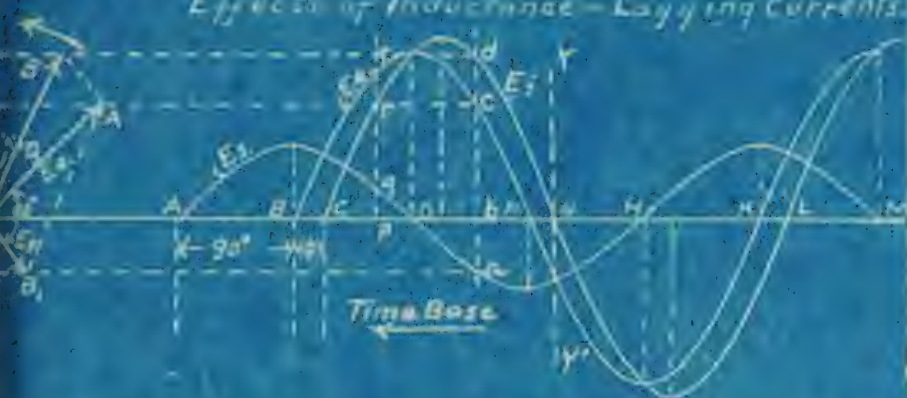
Check: Interchange instruments without altering relative connections of current and Emf. coils of wattmeters; then,

(a) If deflections are now in same direction as before,
Sum of original readings = power; $P = W_1 + W_2$.

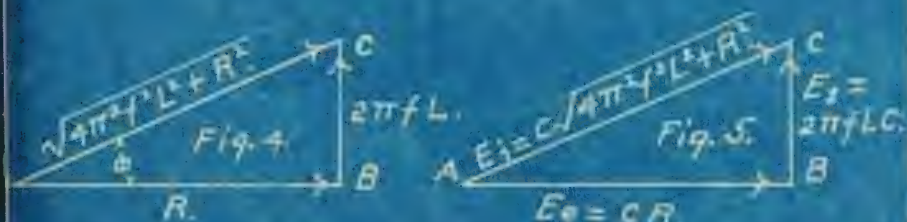
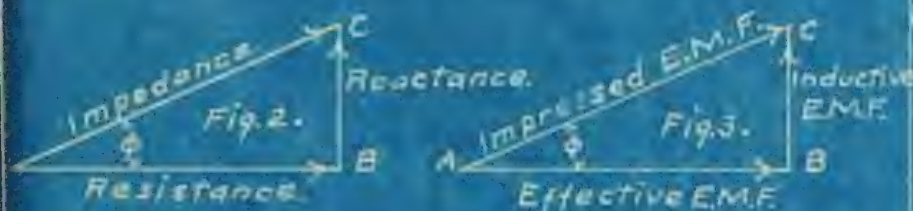
(b) If deflections are now reversed,
difference of original readings = power; $P = W_1 - W_2$.

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Fig. 1. Alternating Current Relations - Effects of Inductance - Laying Currents.



Invariable Relation of Mean Values: $E_e = \sqrt{E_1^2 + E_2^2}$
 Instantaneous values are projections of mean values in
 several angular positions: $E_e = \Sigma(E_1 \pm E_2)$
 vs. $bc = bd - ab$; and $pt = pq + pr$

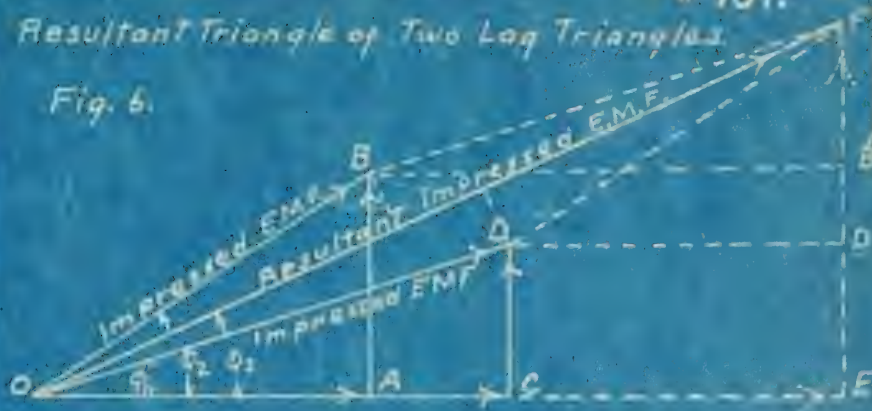


Resistance Triangles.

E.M.F. Triangles.

#181. Resultant Triangle of Two Lag Triangles.

Fig. 6.



- (1) $OE = OA + OC.$ (2) $EF = AB + CD.$
- (3) $OE = OF \cos \phi_3 = OD \cos \phi_1 + OB \cos \phi_2.$
- (4) $EF = OF \sin \phi_3 = OD \sin \phi_1 + OB \sin \phi_2.$
- (5) $OF = \text{geometric sum of } OB \text{ and } OD.$
- (6) $OF = OB \cos(\phi_1 - \phi_2) + OD \cos(\phi_2 - \phi_1).$
- (7) $\tan \phi_3 = \frac{EF}{OE} = \frac{OD \sin \phi_1 + OB \sin \phi_2}{OD \cos \phi_1 + OB \cos \phi_2}.$

$$\text{Power Factor} = \cos \phi = \frac{\text{Resistance}}{\text{Impedance}} = \frac{R}{\sqrt{R^2 + 4\pi^2 L^2}}$$

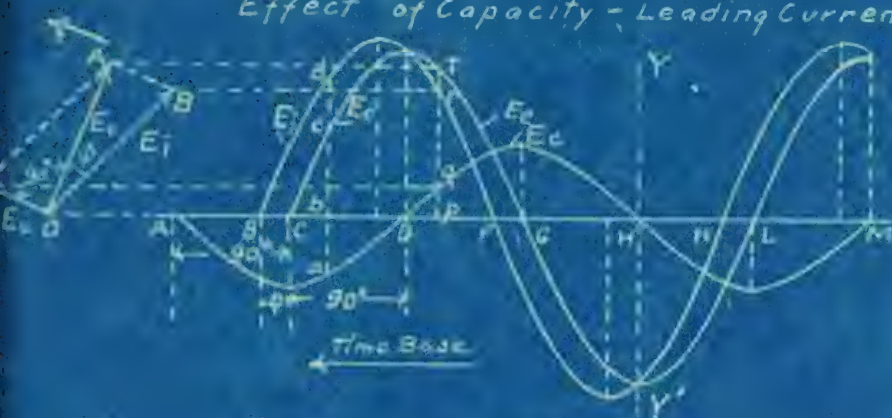
$$\cos \phi = \frac{\text{Effective E.M.F.}}{\text{Impressed E.M.F.}} = \frac{E_e}{E_i} = \frac{E_e}{\sqrt{E_1^2 + E_2^2}}$$

$$\text{Induction Factor} = \sin \phi = \frac{\text{Reactance}}{\text{Impedance}} = \frac{2\pi fL}{\sqrt{R^2 + 4\pi^2 L^2}}$$

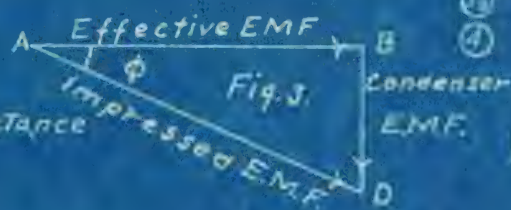
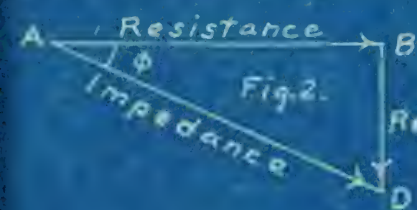
$$\sin \phi = \frac{\text{Inductive E.M.F.}}{\text{Impressed E.M.F.}} = \frac{E_s}{E_i} = \frac{E_s}{\sqrt{E_1^2 + E_2^2}}$$

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Fig. 1. Alternating Current Relations,
Effect of Capacity - Leading Currents.



Invariable Relation of Mean Values: $E_e = \sqrt{E_i^2 - E_c^2}$.
Instantaneous values are projections of mean values in
several angular positions: $E_e' = \Sigma(E_i' \pm E_c')$.
Thus: $bc = bd - ab$; and, $pt = pr + pq$.



Resistance Triangles.

E.M.F. Triangles.

Resultant Triangle of Two Lead Triangles



- ① $OE = OA + OC$.
- ② $EF = AB + CD$.
- ③ $OE = OF \cos \phi_1 = OD \cos \phi_1 + OB \cos \phi_2$.
- ④ $EF = OF \sin \phi_1 = OB \sin \phi_1 + OD \sin \phi_2$.
- ⑤ $OF =$ geometric sum of OB and OD .
- ⑥ $OF = OB \cos(\phi_2 - \phi_1) + OD \cos(\phi_2 - \phi_1)$.
- ⑦ $\tan \phi_1 = \frac{EF}{OE} = \frac{OB \sin \phi_1 + OD \sin \phi_2}{OB \cos \phi_1 + OD \cos \phi_2}$.

$$\text{Power Factor} = \cos \phi = \frac{\text{Resistance}}{\text{Impedance}} = \frac{R}{\sqrt{R^2 + 4\pi^2 f^2 k^2}}$$

$$\cos \phi = \frac{\text{Effective EMF}}{\text{Impressed EMF}} = \frac{E_e}{E_i} = \frac{E_c}{\sqrt{E_c^2 + E_c^2}}$$

$$\text{Induction Factor} = \sin \phi = \frac{\text{Reactance}}{\text{Impedance}} = \frac{1}{\sqrt{R^2 + 4\pi^2 f^2 k^2}}$$

$$\sin \phi = \frac{\text{Condenser EMF}}{\text{Impressed EMF}} = \frac{E_c}{E_i} = \frac{E_c}{\sqrt{E_c^2 + E_c^2}}$$

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Alternating Current Relations,

Effect of Combined Inductance and Capacity-Lagging, Phasing, or Leading Currents.



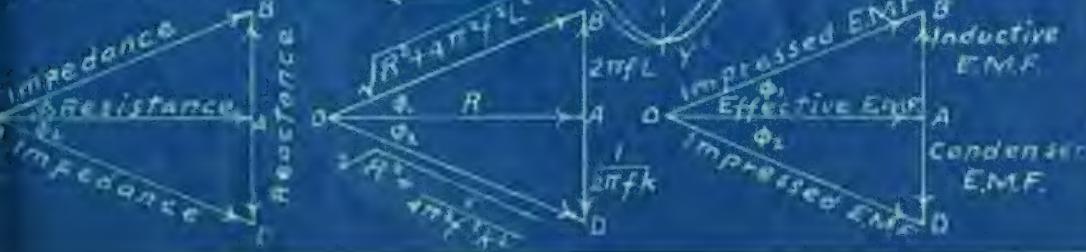
Case I.
Lag > Lead.



Case II.
Lag = Lead.



Case III.
Lag < Lead.



Combinations of Inductance and capacity to secure zero lag.

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Case A: Inductances I-1.



Inductances in series alone.

$E_1' E_2' = AC$ Emf. of Ind. Res.
 $E_1' E_2' = AC$ Emf. of non-Ind. Res.
 $C_1 C_2 =$ Cur. in Ind. Res.
 $E_1' E_2' = DC$ Emf. of Ind. Res.
 $E_1' E_2' =$ Inductive Emfs.

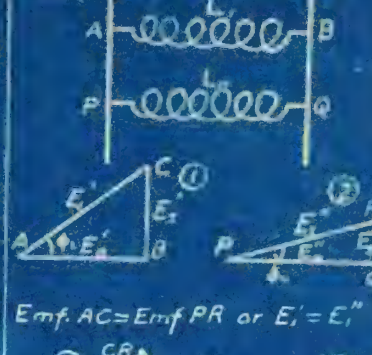
I-2.



Ind. resistances in series with non-ind. resistance.

$E_1' E_2' = AC$ Emf. of Ind. Res.
 $E_1' E_2' = AC$ Emf. of non-Ind. Res.
 $C_1 C_2 =$ Cur. in Ind. Res.
 $E_1' E_2' = DC$ Emf. of Ind. Res.
 $E_1' E_2' =$ Inductive Emfs.

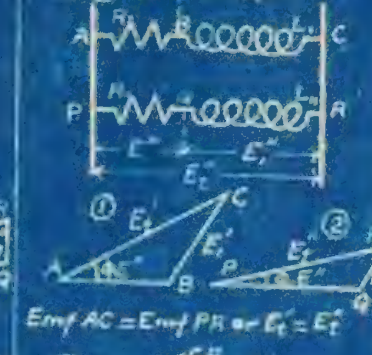
II-1.



Inductances in parallel alone.

$E_1' E_2' = AC$ Emf. of Ind. Res.
 $E_1' E_2' = AC$ Emf. of non-Ind. Res.
 $C_1 C_2 =$ Cur. in Ind. Res.
 $E_1' E_2' = DC$ Emf. of Ind. Res.
 $E_1' E_2' =$ Inductive Emfs.

II-2.



Inductances and resistances in series parallel.

$E_1' E_2' = AC$ Emf. of Ind. Res.
 $E_1' E_2' = AC$ Emf. of non-Ind. Res.
 $C_1 C_2 =$ Cur. in Ind. Res.
 $E_1' E_2' = DC$ Emf. of Ind. Res.
 $E_1' E_2' =$ Inductive Emfs.

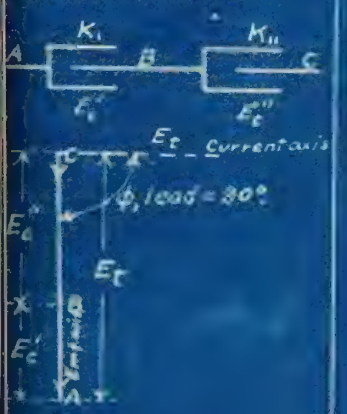
II-3.



Inductances and resistances in series parallel.

$E_1' E_2' = AC$ Emf. of Ind. Res.
 $E_1' E_2' = AC$ Emf. of non-Ind. Res.
 $C_1 C_2 =$ Cur. in Ind. Res.
 $E_1' E_2' = DC$ Emf. of Ind. Res.
 $E_1' E_2' =$ Inductive Emfs.

Case B: Capacities I-1.



Capacities in series alone.

$E_1' E_2' = AC$ Emf. of Ind. Res.
 $E_1' E_2' = AC$ Emf. of non-Ind. Res.
 $C_1 C_2 =$ Cur. in Ind. Res.
 $E_1' E_2' = DC$ Emf. of Ind. Res.
 $E_1' E_2' =$ Inductive Emfs.

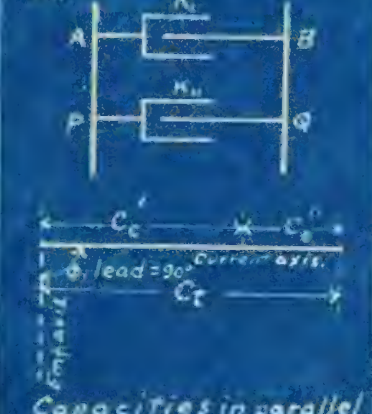
I-2.



Capacities in series with non-ind. resistance.

$E_1' E_2' = AC$ Emf. of Ind. Res.
 $E_1' E_2' = AC$ Emf. of non-Ind. Res.
 $C_1 C_2 =$ Cur. in Ind. Res.
 $E_1' E_2' = DC$ Emf. of Ind. Res.
 $E_1' E_2' =$ Inductive Emfs.

II-1.



Capacities in parallel alone.

$E_1' E_2' = AC$ Emf. of Ind. Res.
 $E_1' E_2' = AC$ Emf. of non-Ind. Res.
 $C_1 C_2 =$ Cur. in Ind. Res.
 $E_1' E_2' = DC$ Emf. of Ind. Res.
 $E_1' E_2' =$ Inductive Emfs.

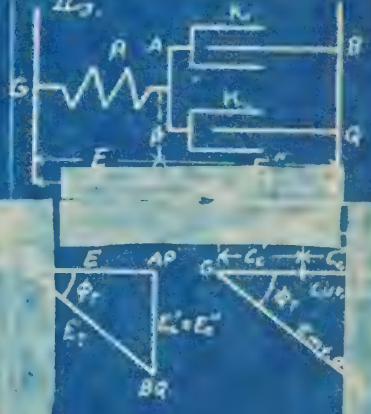
II-2.



Capacities and resistances in series parallel.

$E_1' E_2' = AC$ Emf. of Ind. Res.
 $E_1' E_2' = AC$ Emf. of non-Ind. Res.
 $C_1 C_2 =$ Cur. in Ind. Res.
 $E_1' E_2' = DC$ Emf. of Ind. Res.
 $E_1' E_2' =$ Inductive Emfs.

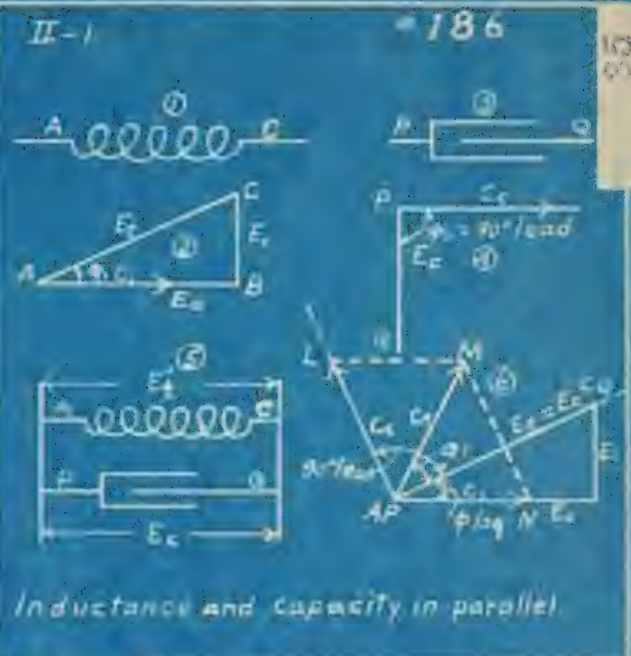
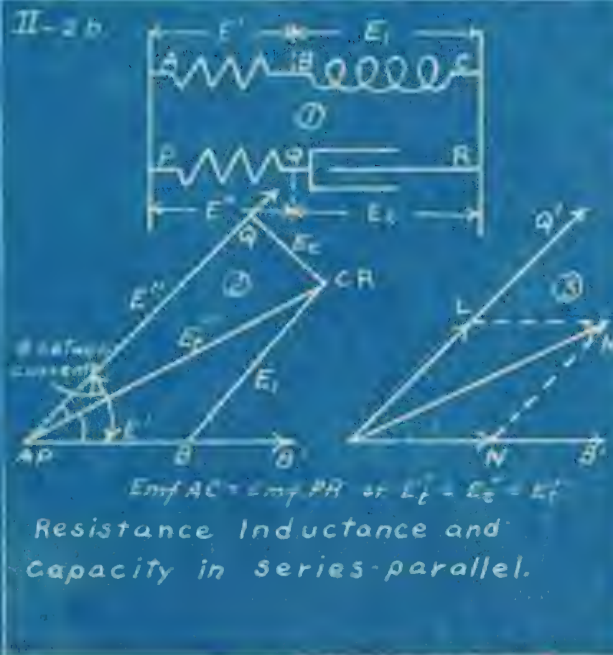
II-3.



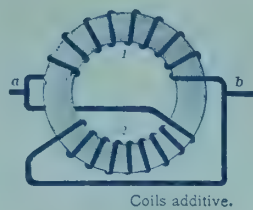
Capacities and resistances in series parallel.

$E_1' E_2' = AC$ Emf. of Ind. Res.
 $E_1' E_2' = AC$ Emf. of non-Ind. Res.
 $C_1 C_2 =$ Cur. in Ind. Res.
 $E_1' E_2' = DC$ Emf. of Ind. Res.
 $E_1' E_2' =$ Inductive Emfs.

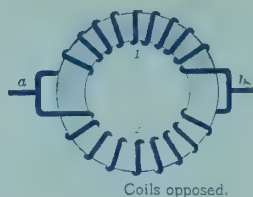
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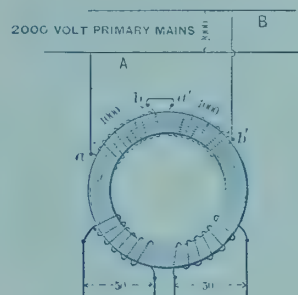
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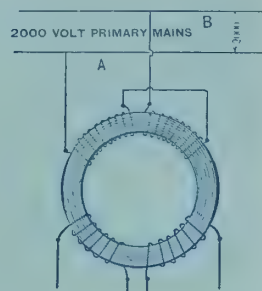
Coils additive.



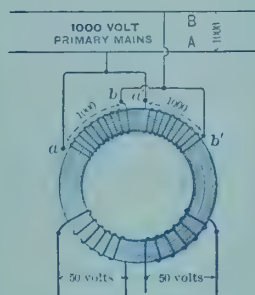
Coils opposed.



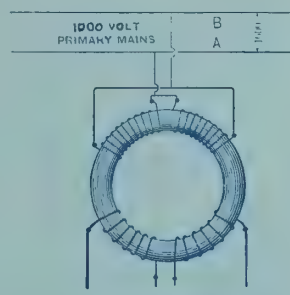
Correct connection of primaries in series.



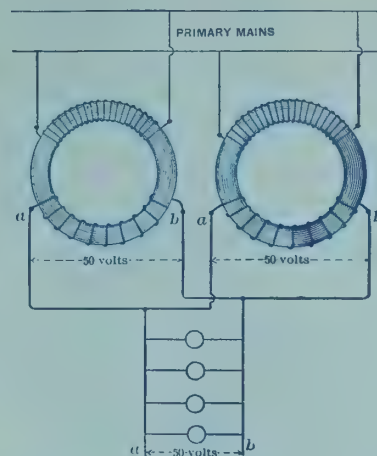
Incorrect connection of primaries in series.



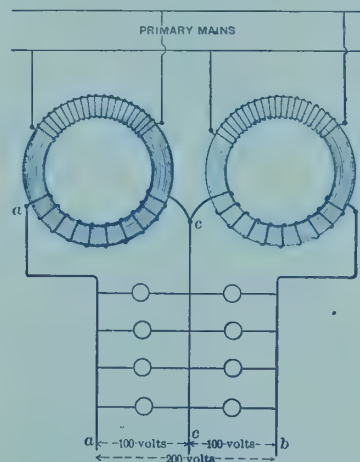
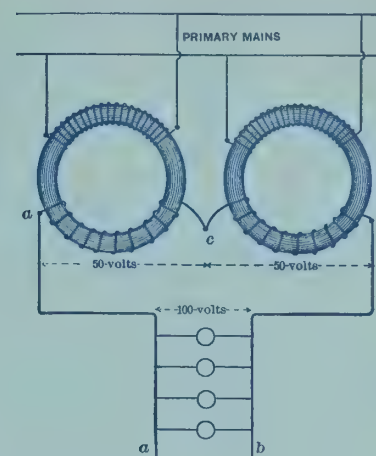
Correct connection of primaries in parallel.



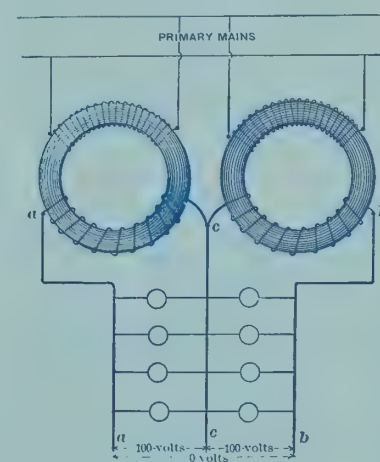
Incorrect connection of primaries in parallel.



"Banking" transformers: secondaries connected in parallel. Two 50-volt secondaries connected in series to supply 100-volt lamps.



Transformers connected for three-wire system.



Incorrect connection for three-wire system.

Correct and Incorrect Connections of Transformers. Bedell's Principles of the Transformer.

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Double Voltage Test for Insulation Strength between Turns.



Heating Test by Opposition Method

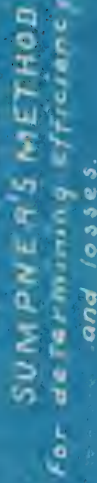


Fig. 4.



Fig. 5.

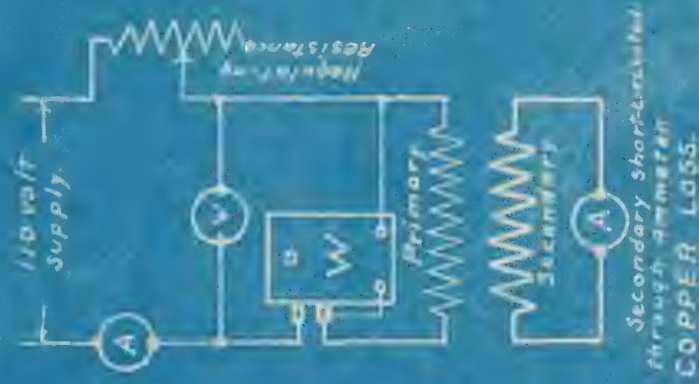
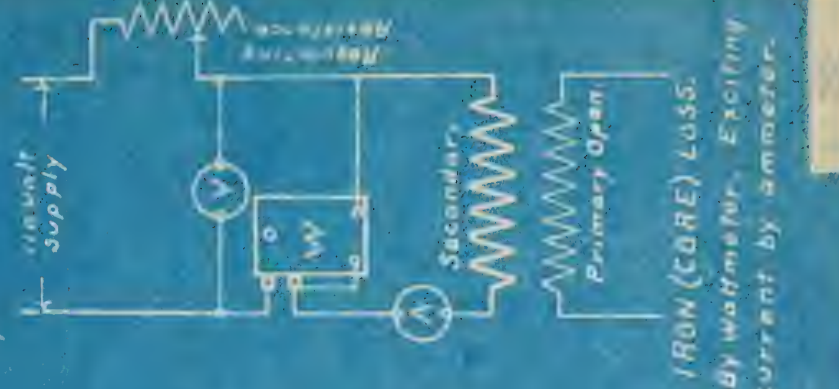
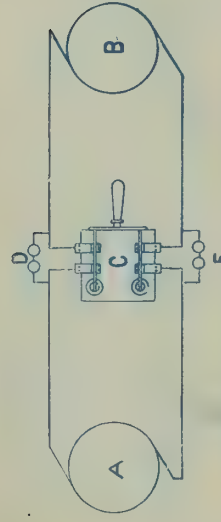


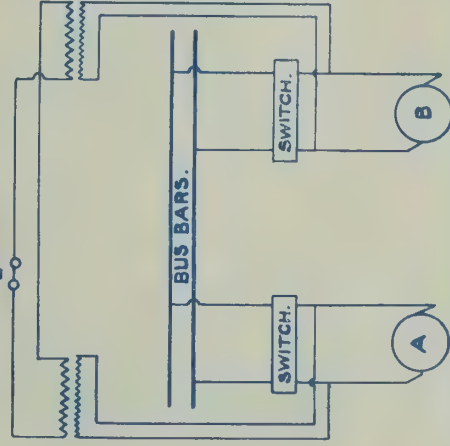
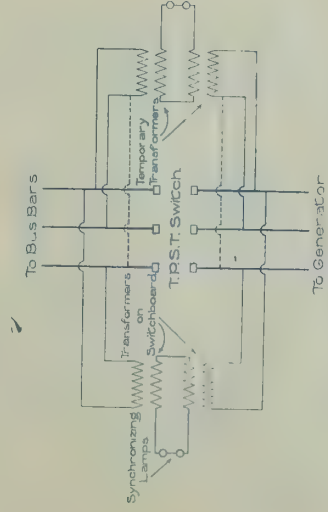
Fig. 6.



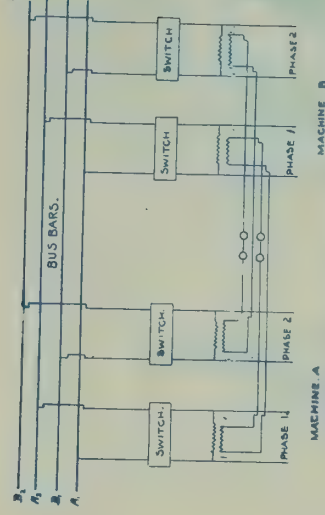
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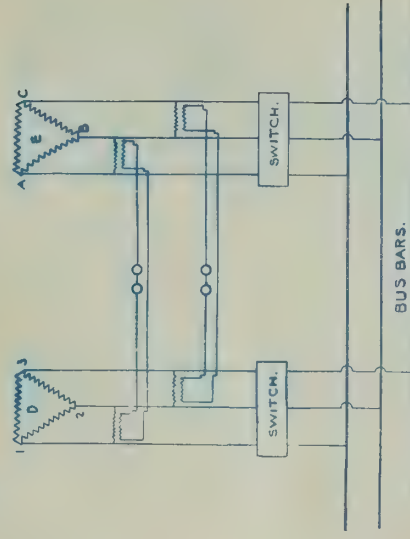
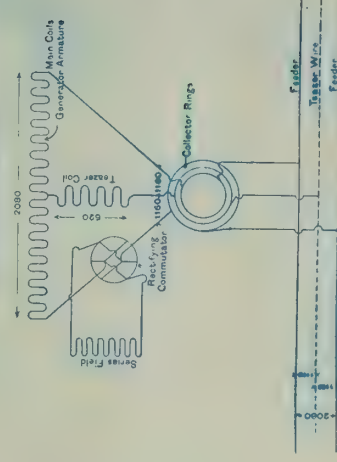
CONNECTIONS FOR PARALLELING LOW VOLTAGE SINGLE PHASE GENERATORS.



CONNECTIONS FOR PARALLELING HIGH VOLTAGE SINGLE PHASE GENERATORS.

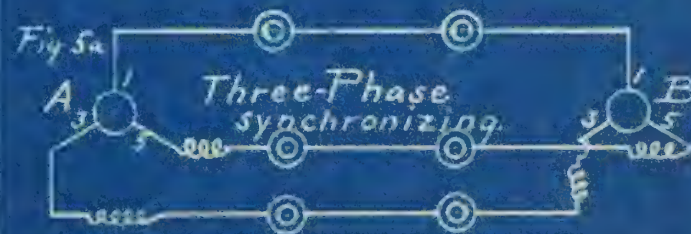
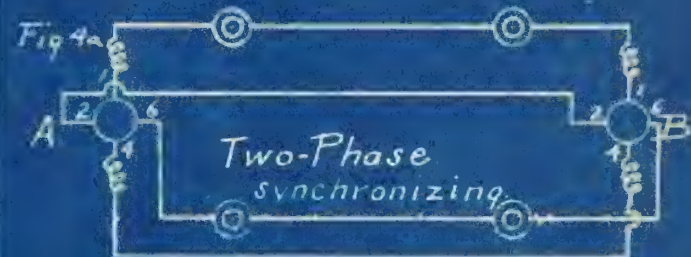
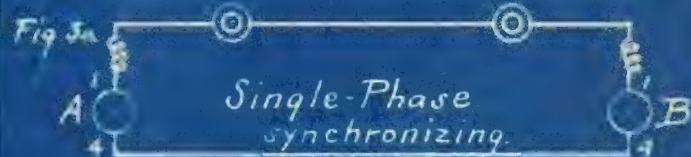
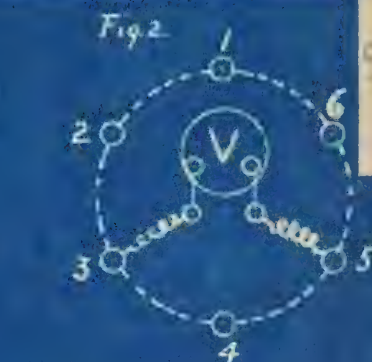
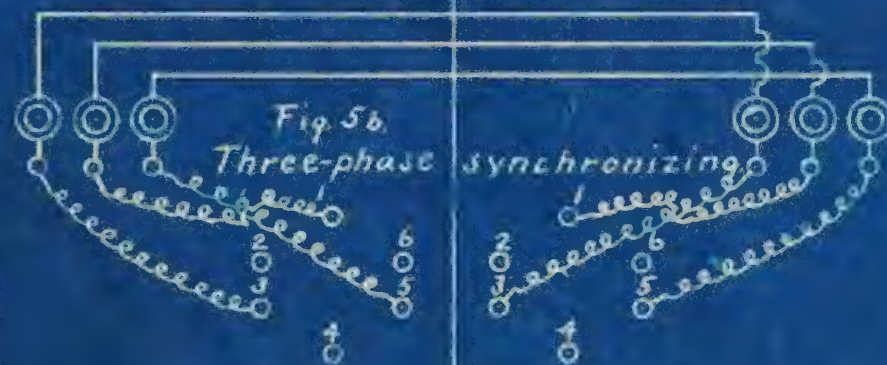
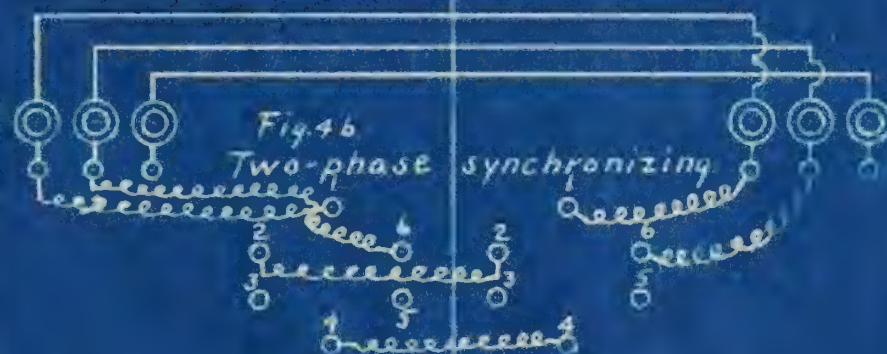
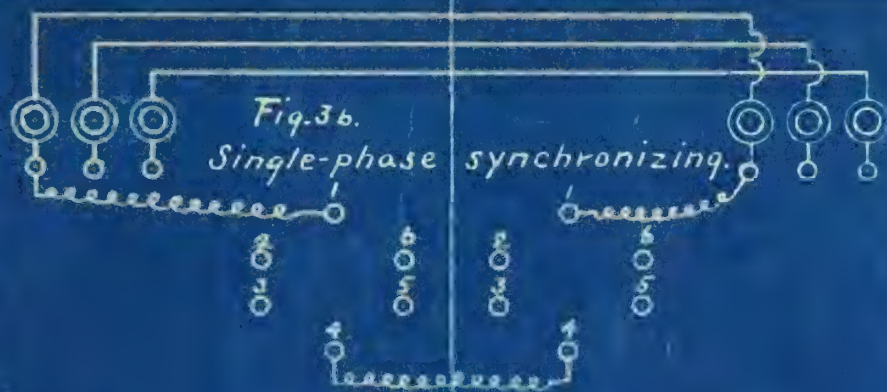


CONNECTIONS FOR PARALLELING TWO-PHASE HIGH VOLTAGE GENERATORS.

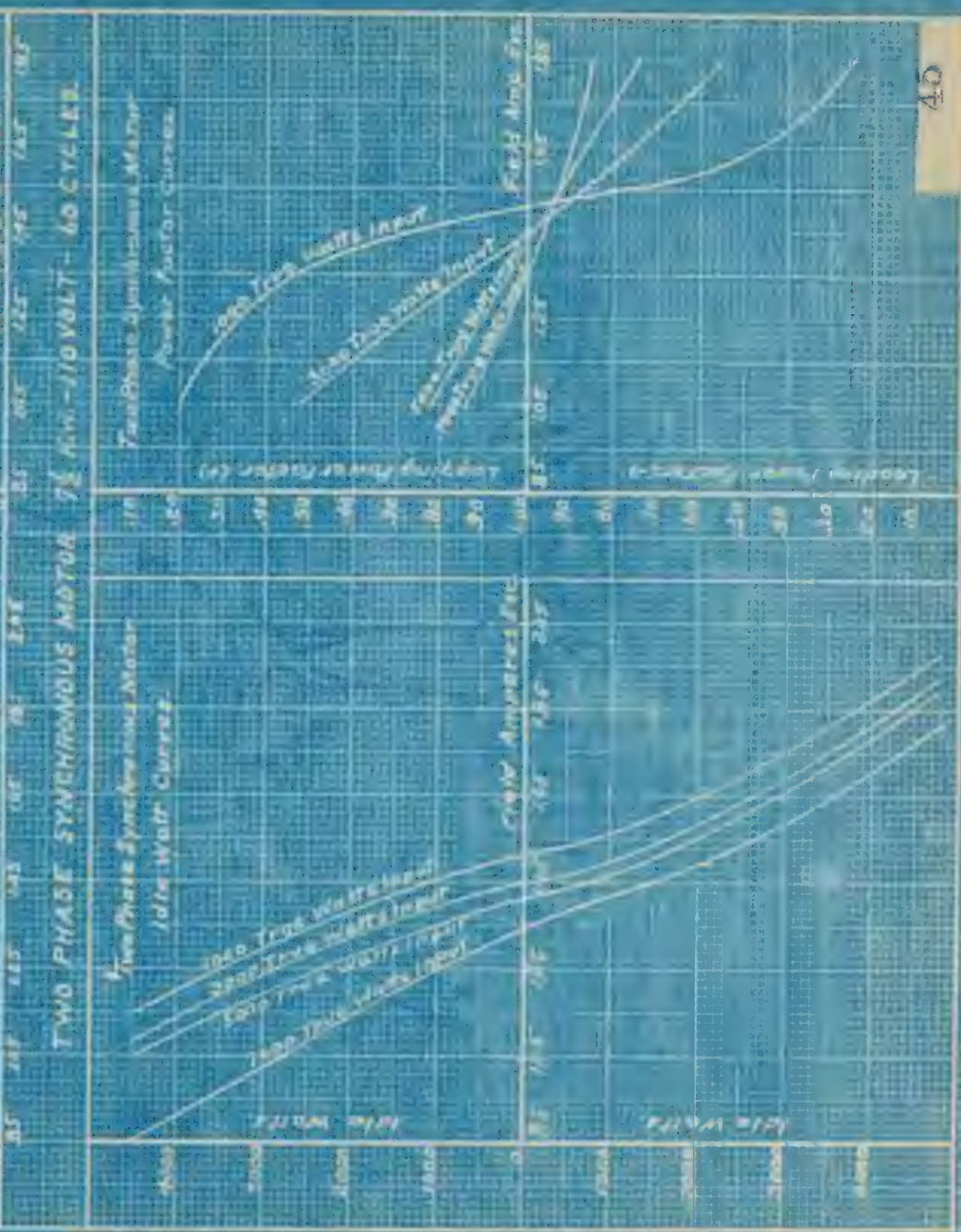
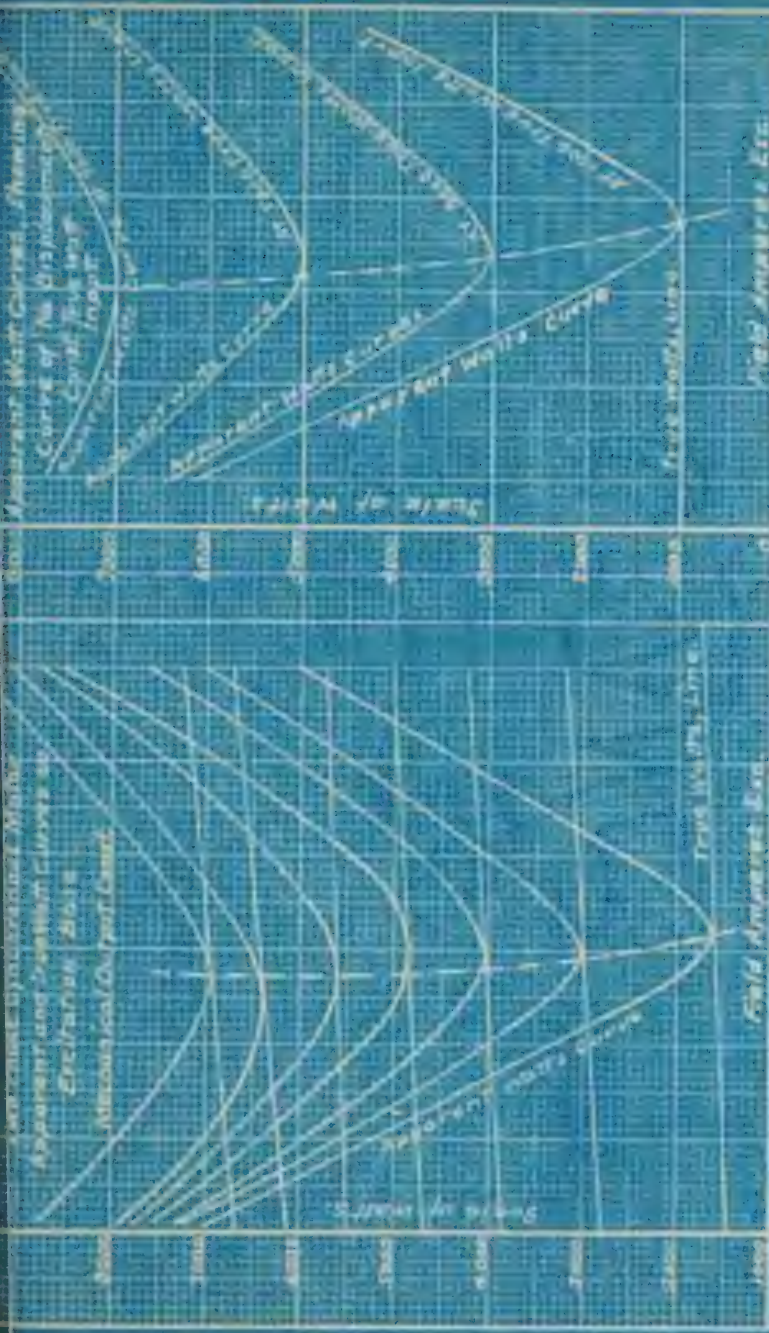


CONNECTIONS FOR PARALLELING THREE-PHASE HIGH VOLTAGE GENERATORS.

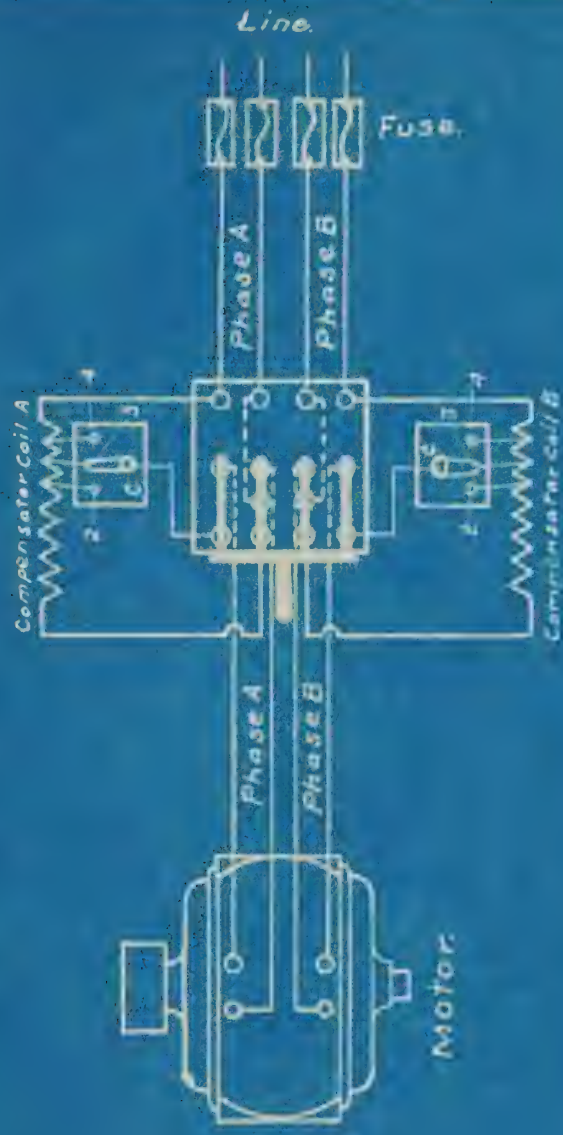
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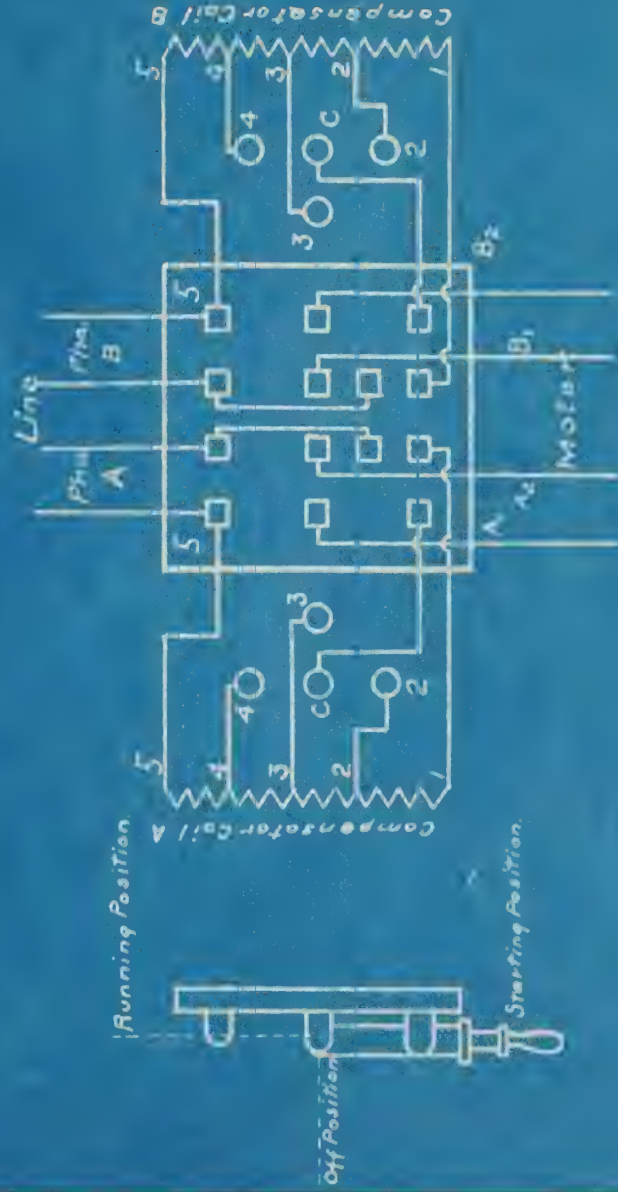


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Switch and Compensator Connections for Starting Westinghouse Two-phase Ind. Motor.

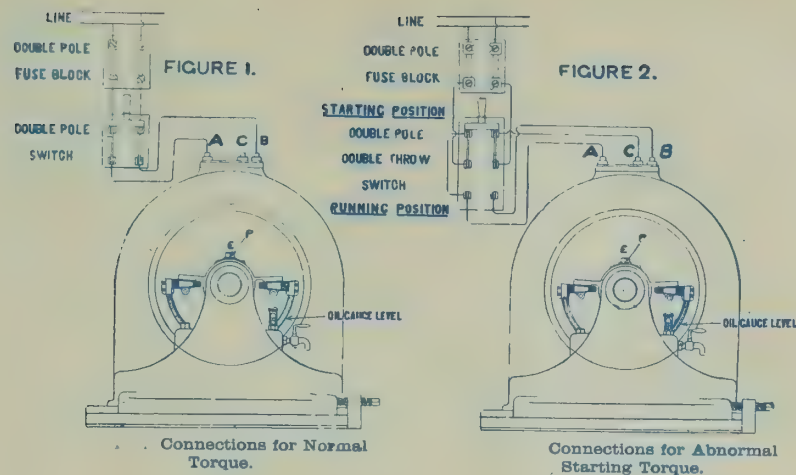
In above diagram switch is thrown to left for starting, and to right for running.



Detail of Compensator Connections.

Variable starting EMF and torque obtained by connecting C to 2, 3, or 4.
 C to 4 gives maximum EMF and torque.
 C to 3 " " " "
 C to 2 " " " "

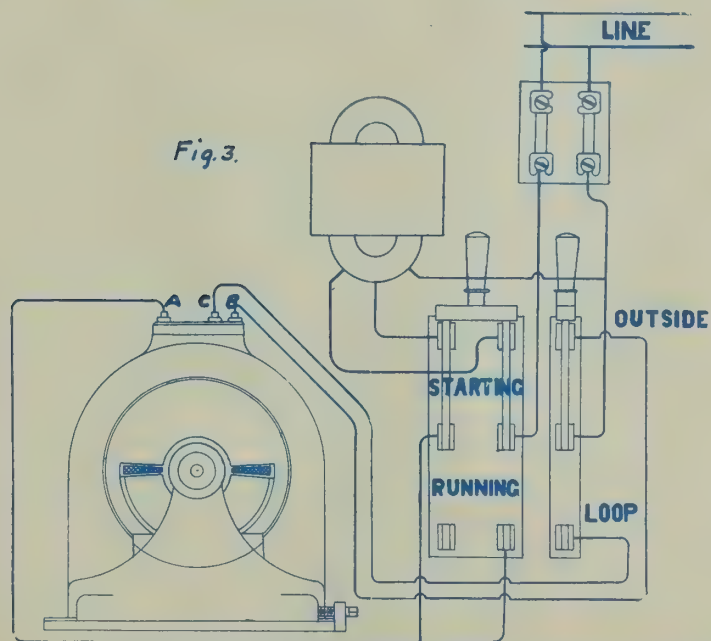
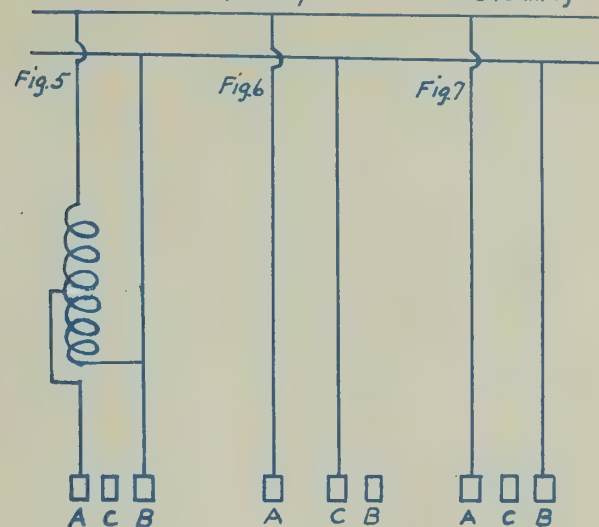
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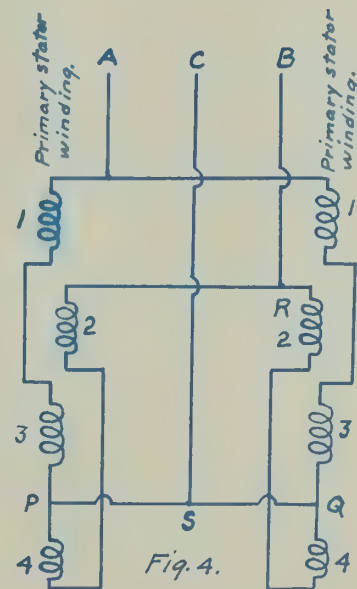
Both switches up
minimum starting
current;

Both switches down
maximum starting
Torque, Heavy load
running.

Double-pole down,
Single-pole up,
Normal starting
and running.



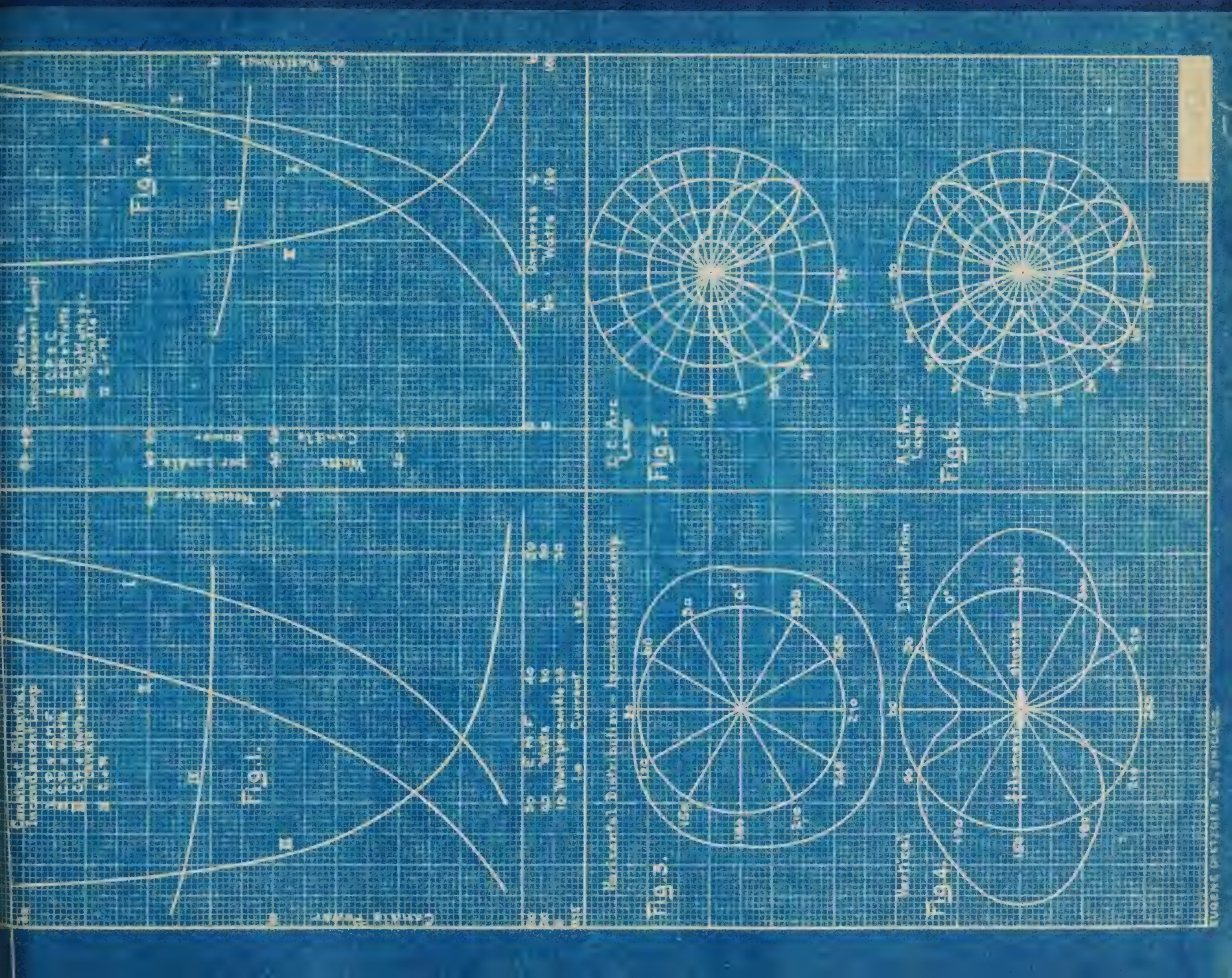
Connections when a Small Reducing Transformer for Holding Down the Starting Current.



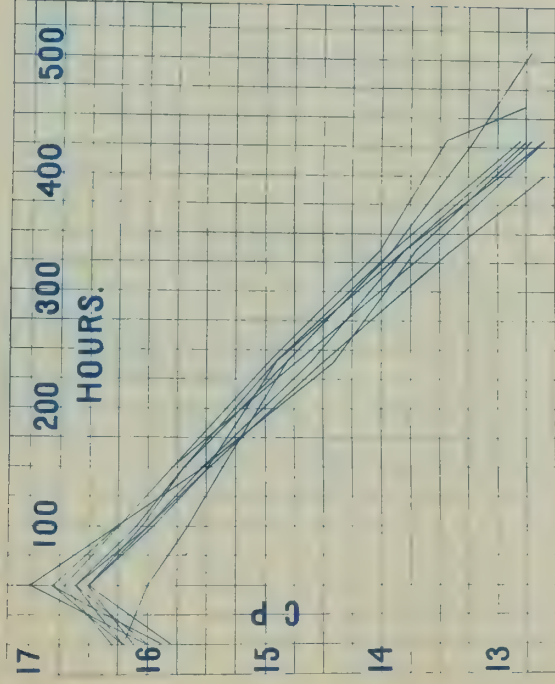
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A blue textured background with a white geometric pattern of intersecting lines forming a triangular grid. Small white dots are scattered along the lines.

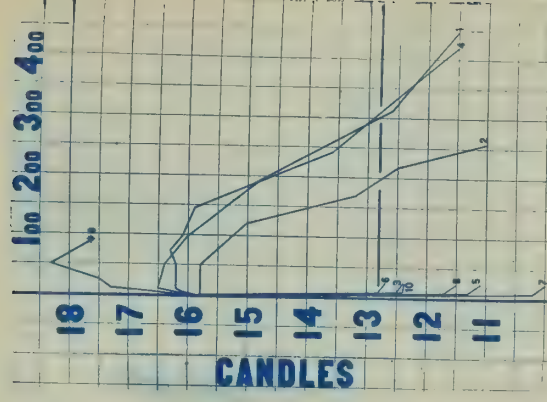
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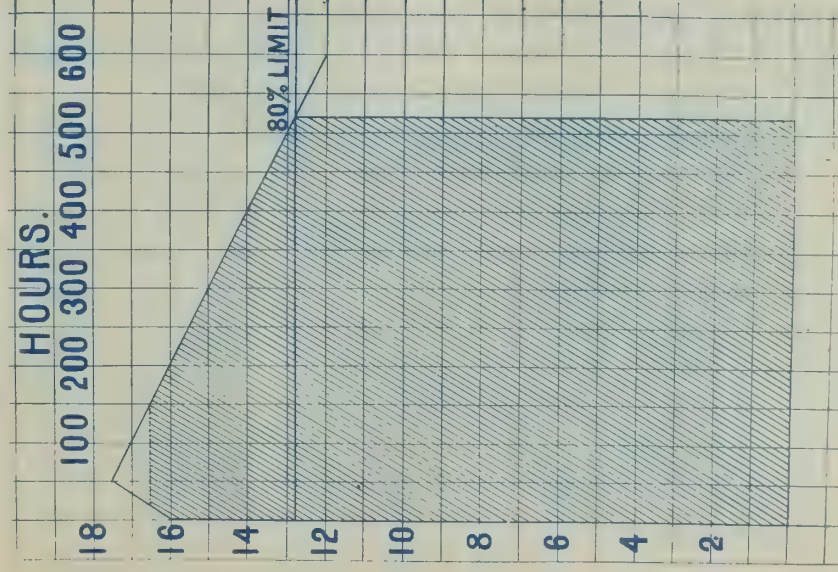
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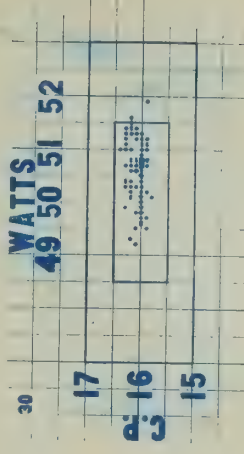
Candle-power performance of ten 16 candle-power 112-volt 3 1/2-watt lamps, showing uniform and good results of well-made lamps.



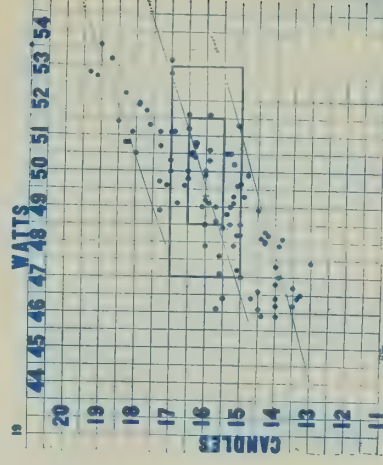
—Target power performance diagram, showing poor results given by ten 16-candle-power 100-volt lamps—3 1/2-watt lamps.



—The candle hour area. The measure of lamp value.

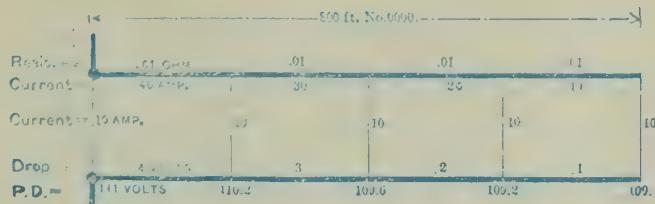


—Target diagram showing results of correctly rated lamps.

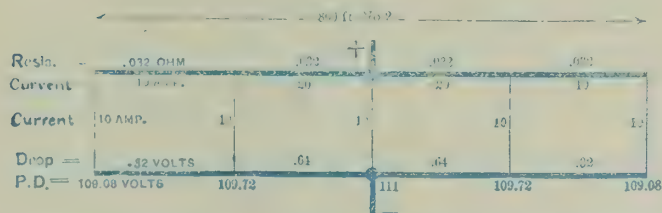


Target diagram showing initial measurements at marked voltage for 100 lamps, rated as 16 candle-power, 50-watt lamps.

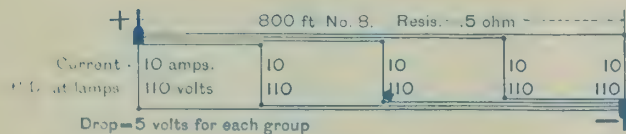
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Feeding at One End of Mains; 1025 lbs. Copper; 2 Volts Max. Difference Between Lamps; 111 Volts at Feeding-Points; 1.2 Volts Average Drop.

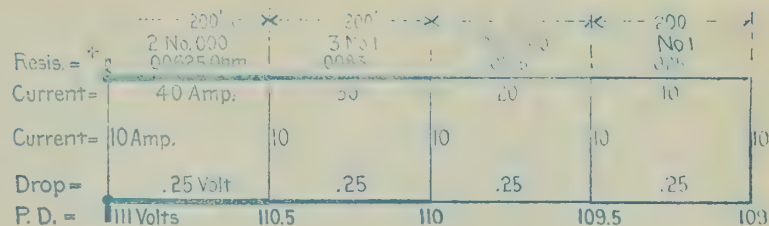


Feeding at Middle of Mains; 321.5 lbs. Copper; 1.92 Volts Max. Difference Between Lamps; 111 Volts at Feeding-Points; 1.3 Volts Average Drop.

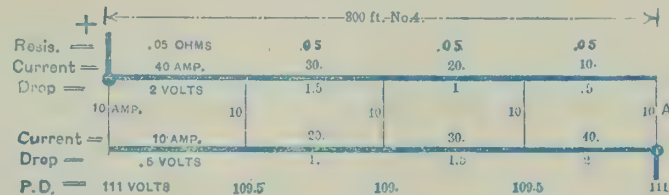


Drop=5 volts for each group

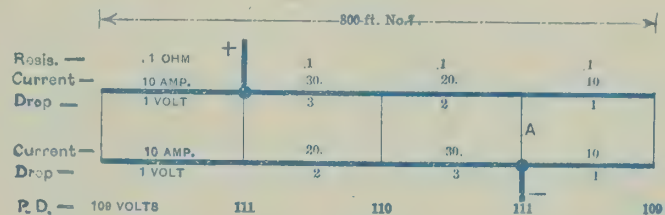
Equal Conductors; Equal Total Lengths; 200 lbs. Copper; No Difference of Voltage Between Lamps; 115 Volts Between Feeding-Points; 5 Volts Drop.



Tapering Mains; 1,013 lbs. of Copper; 2 Volts Max. Difference Between Lamps; 111 Volts at Feeding-Points; 1 Volt Average Drop.

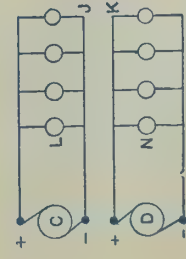


Feeding at Opposite Ends of Mains; 202.2 lbs. Copper; 2 Volts Max. Difference Between Lamps; 116 Volts Between Feeding-Points; 6 Volts Average Drop

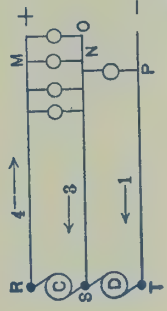


Feeding at Distributed Points on Mains; 101 lbs. of Copper; 2 Volts Max. Difference Between Lamps; 116 Volts Between Feeding-Points; 6 Volts Average Drop.

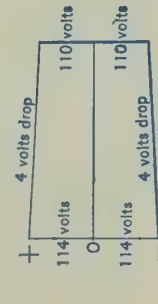
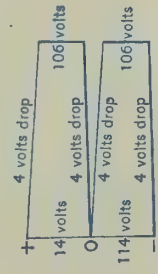
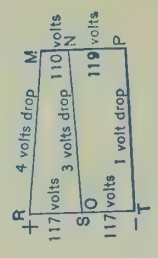
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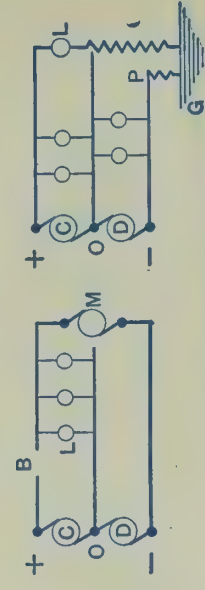
Evolution of the Three-Wire System.



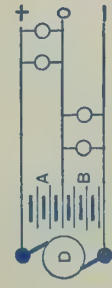
Three-Wire System.



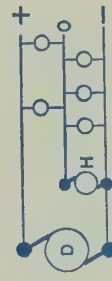
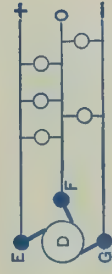
Three-Wire System.



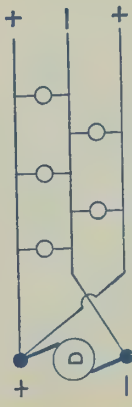
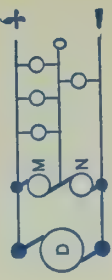
Peculiar Conditions on Three-Wire System.



Three-Wire Systems.



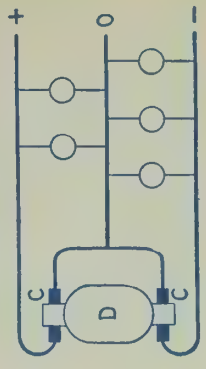
Three-Wire Systems.



Conversion from Three-Wire to Two-Wire System.



Bridge Arrangement of Three-Wire System.



Three-Wire System with Double Dynamo.

Crocker's Electric Lighting, Vol. II.

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PARALLEL AND THREE-WIRE DISTRIBUTION.



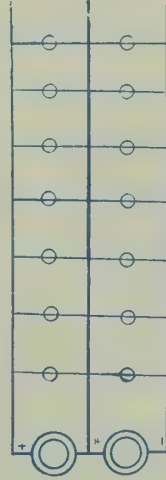
Series—Multiple.



Series—Multiple, with Neutral.



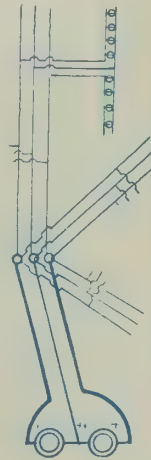
Three Wire, with Three-Brush Dynamo.



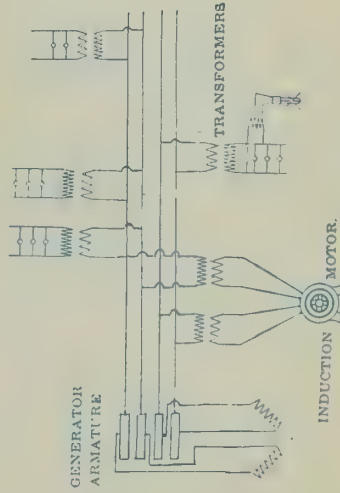
Three-Wire, Two Dynamos.



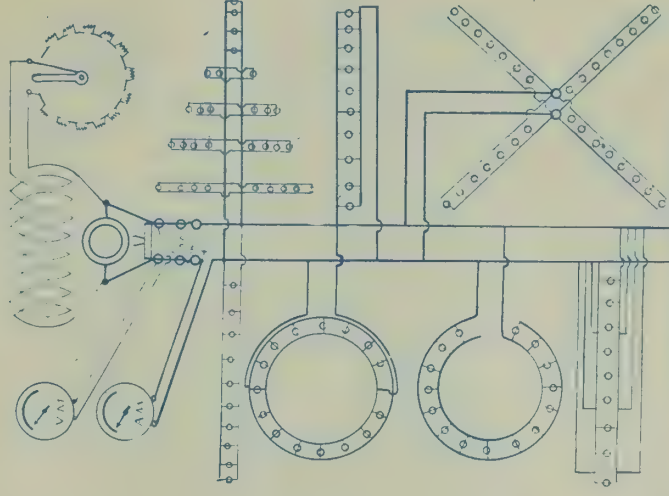
Three-Wire, Storage Battery.



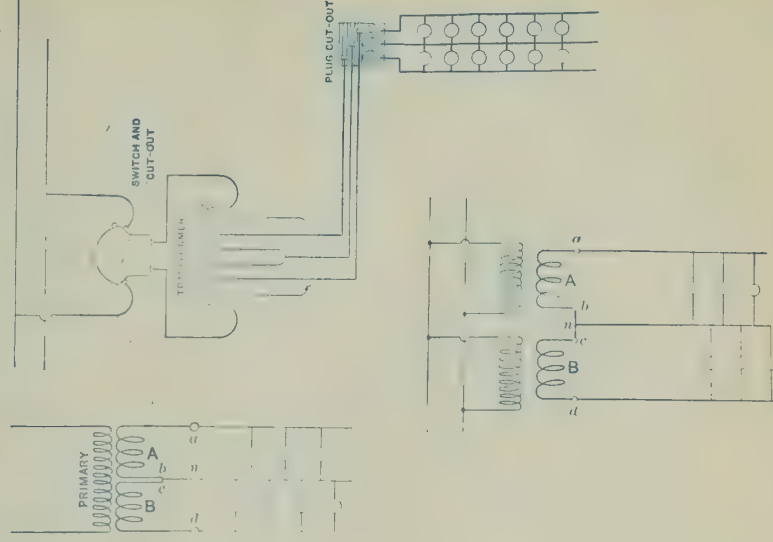
Three-Wire Feeder and Main Distribution.



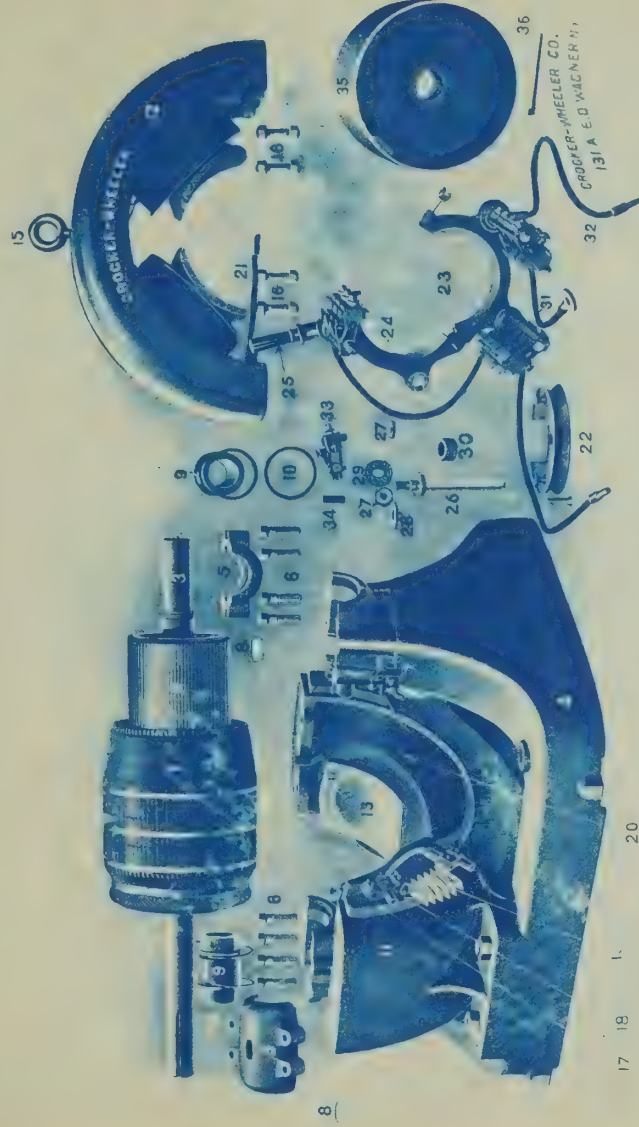
Two-Phase, Four-Wire Distribution.



Types of Two-Wire Distribution.



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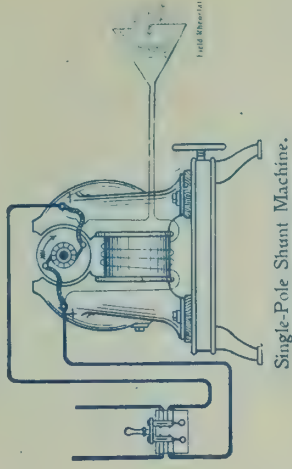


DISSECTED DYNAMO.

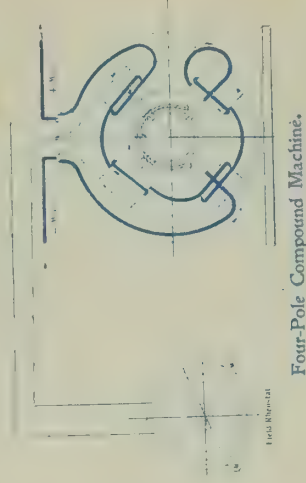
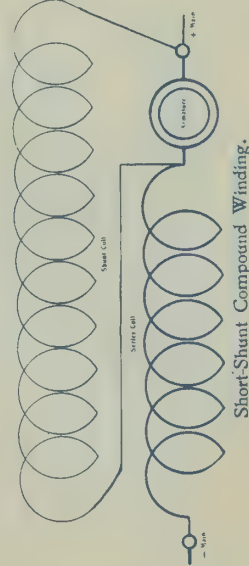
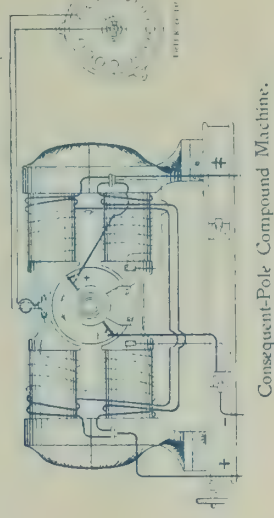
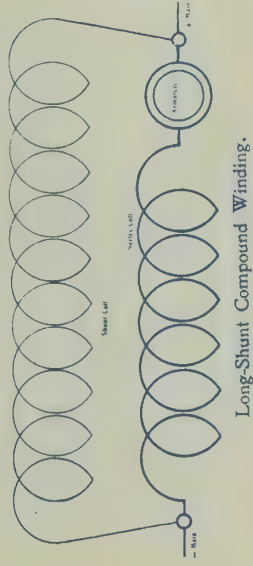
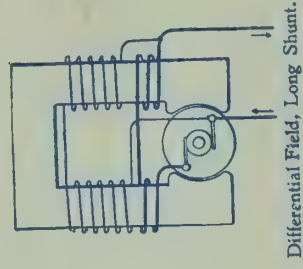
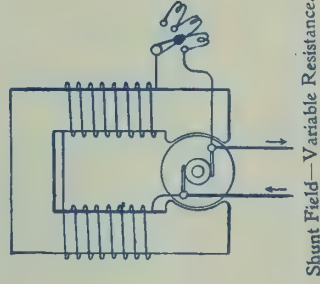
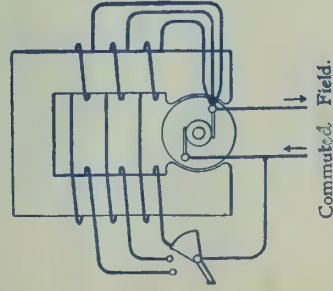
1. Armature (includes 2 and 3).
2. Commutator.
3. Shaft.
4. Base.
5. Bearing Cap.
6. Bearing Cap Screws.
7. Oil Cock.
8. Oil Hole Cover.
9. Journal Box.
10. Oil Ring.
11. Lower Magnet Frame (includes 13 and 14).
12. Upper Magnet Frame (includes 13 and 14).
13. Pole.
14. Pole Shoe.
15. Eye Bolt.
16. Magnet Frame Bolts.
17. Terminal Board.
18. Terminal Block.
19. Compounding Rectifier.—**Series Shunt.**
20. Field Coil.
21. Field Cable.
22. Rocker Seat with Screws.
23. Brush Rigging (includes 24, 25, 26, 27, 28).
24. Rocker (includes 25.)
25. Rocker Handle.
26. Brush Stud.
27. Brush Stud Nut.
28. Brush Stud Insulating Washer (Round Hole).
29. Brush Stud Insulating Washer (Oval Hole).
30. Brush Stud Insulating Sleeve.
31. Brush Stud Cable.
32. Armature Cable.
33. Brush Holder.
34. Brush.
35. Pulley.
36. Pulley Key.

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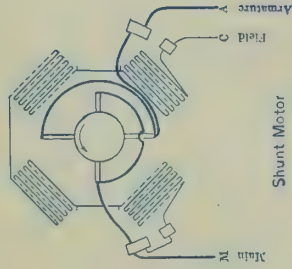
DIRECT-CURRENT MACHINE WINDINGS.



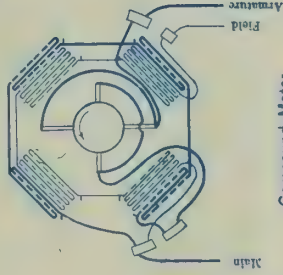
CONNECTIONS FOR MOTOR REGULATION.



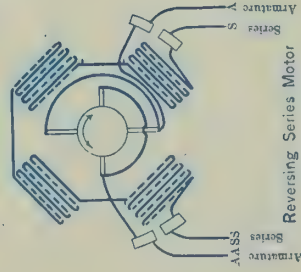
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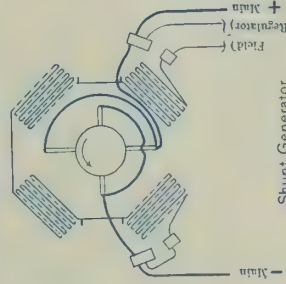
Shunt Motor



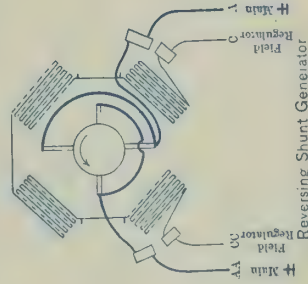
Compound Motor



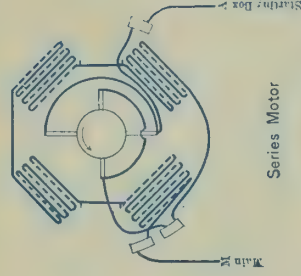
Reversing Series Motor



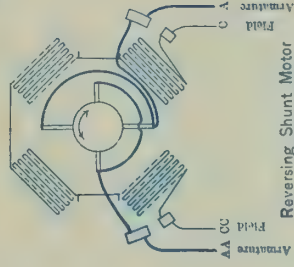
Shunt Generator



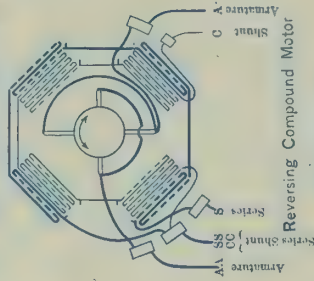
Reversing Shunt Generator



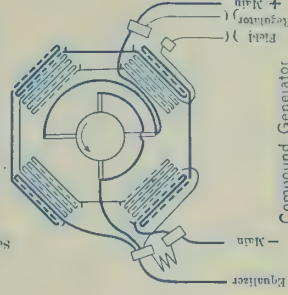
Series Motor



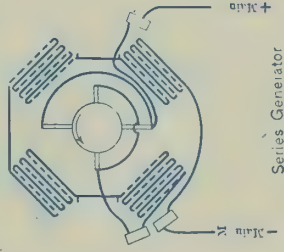
Reversing Shunt Motor



Reversing Compound Motor



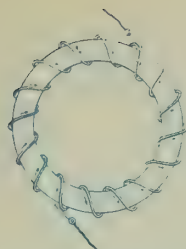
Compound Generator



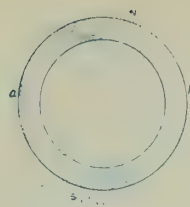
Series Generator

Combinations of 4-pole Machine for various services.-G.E.-W.H. Co.

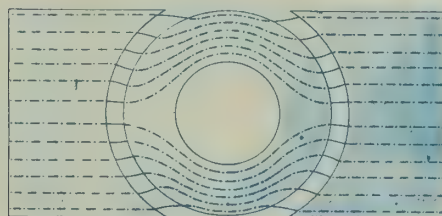
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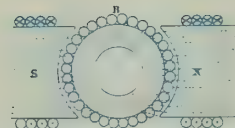
CIRCULATION OF CURRENT AROUND RING ARMATURE.



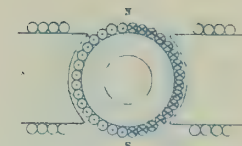
MAGNETIC FIELD DUE TO ARMATURE CURRENT.



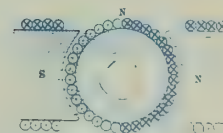
MAGNETIC LINES OF TWO-POLE DYNAMO (UNDISTURBED BY ANY CURRENT IN ARMATURE).



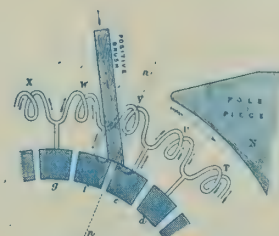
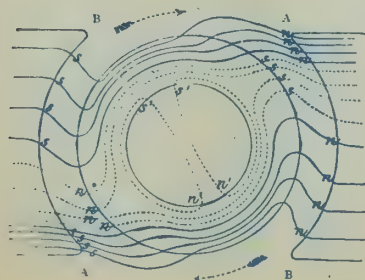
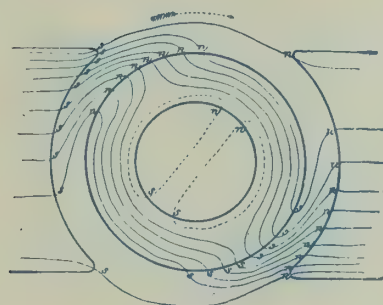
MAGNETIC FLUX THROUGH ARMATURE, WHEN NO CURRENT IS FLOWING.



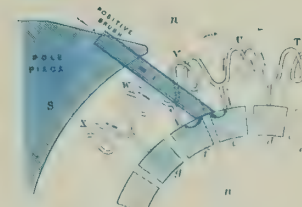
CROSS-MAGNETIZING EFFECT OF THE ARMATURE CURRENT.



JOINT MAGNETIZING EFFECT OF CURRENTS IN FIELD-MAGNET AND ARMATURE (see text).

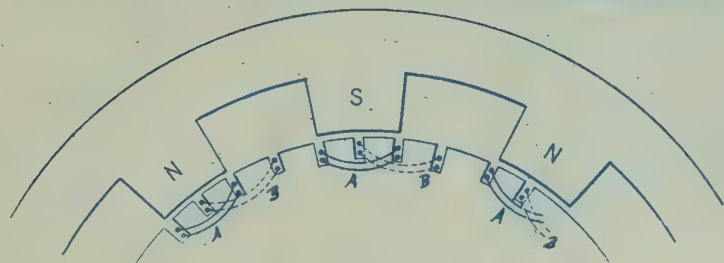


—THE ACT OF COMMUTATION OF A SECTION OF THE ARMATURE OF A GENERATOR.

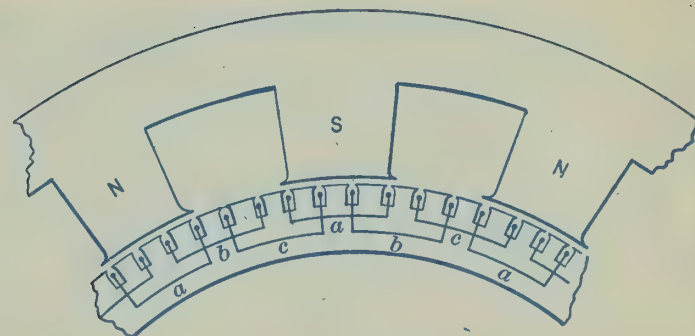


—THE ACT OF COMMUTATION OF A SECTION OF THE ARMATURE OF A MOTOR.

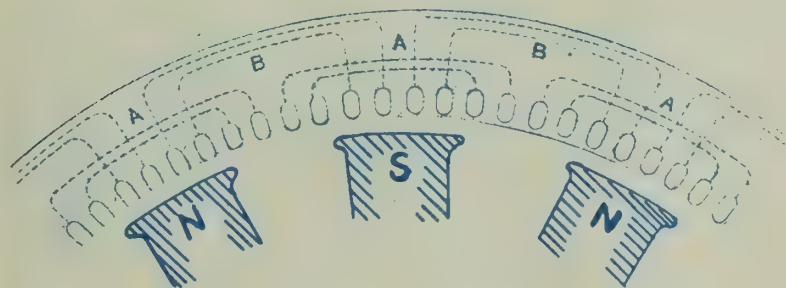
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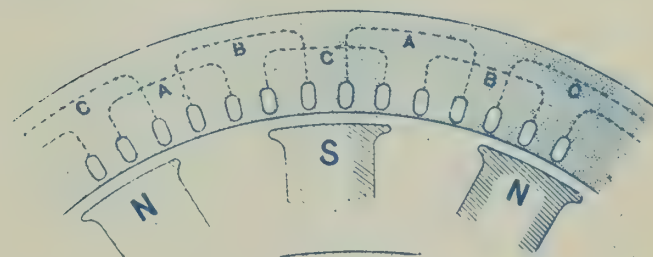
Revolving Armature 2-phase Generator.



Revolving Armature 3-phase Generator.

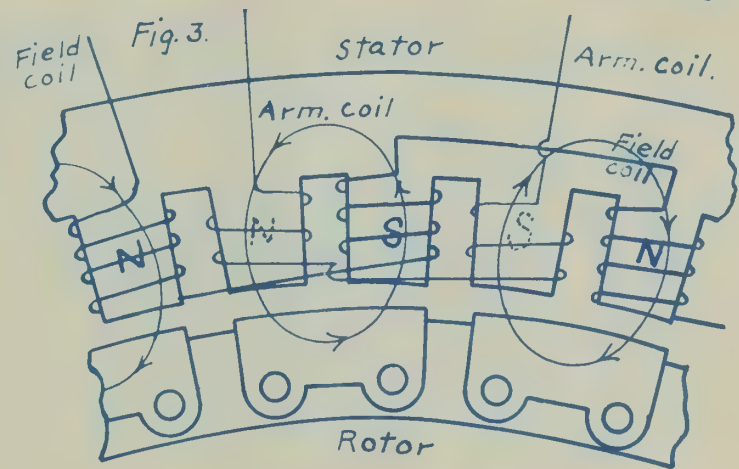
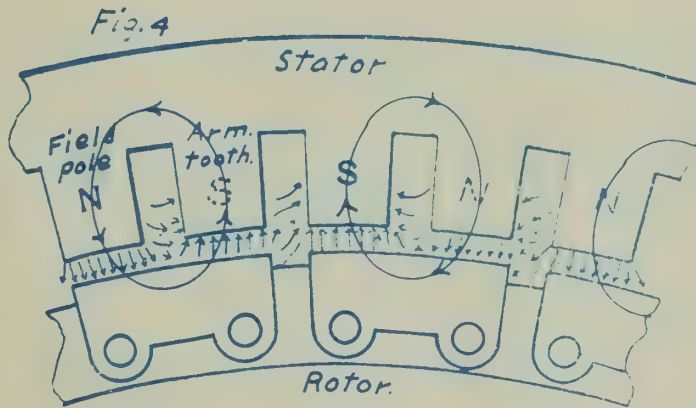
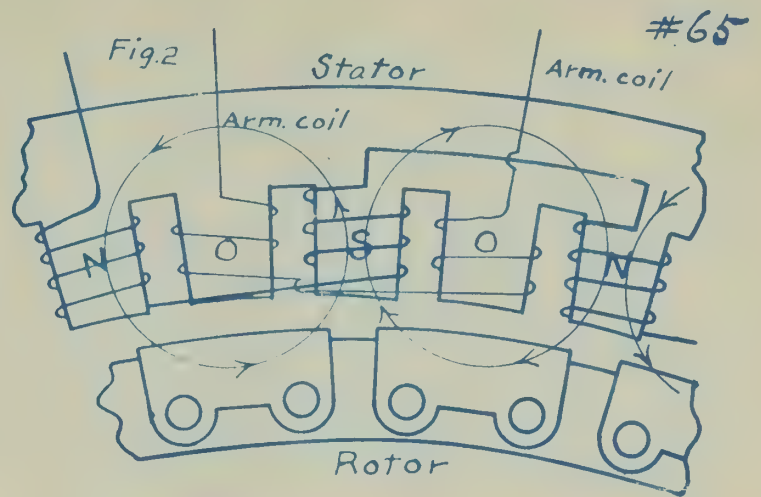
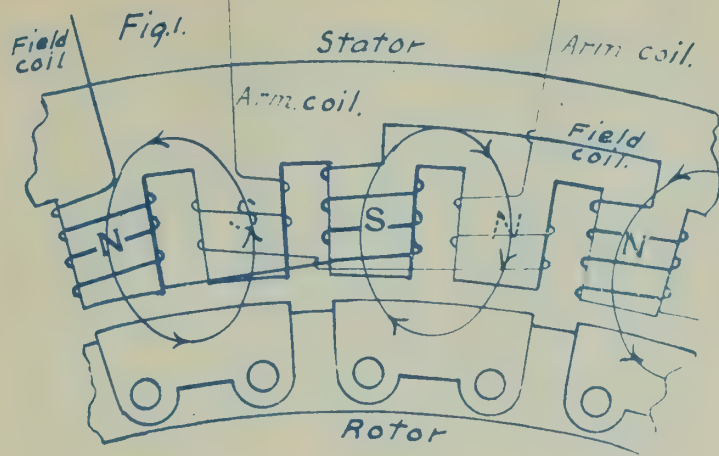


*Revolving Field 2-phase Generator.
All coils A connected in series,
All coils B connected in Series.*



*Revolving Field 3-phase Generator.
All coils A connected in series,
All coils B connected in series,
All coils C connected in series.*

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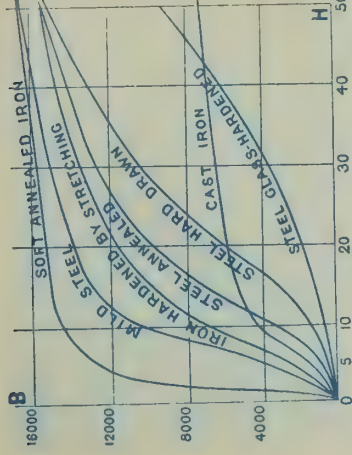


Magnetic Circuit of an Inductor Alternator,
Showing inter-flow of magnetism for different positions of Rotor.

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MAGNETIZATION OR SATURATION (B-H) CURVES, Iron and Steel.

See Thompson's Dynamo-Electric Machinery, 6th Edition, pp. 123-128.
Patereson's Management of Dynamos, pp. 23-25.



—CURVES OF MAGNETIZATION OF VARIOUS SORTS OF IRON.
H—the magnetizing force, or no. of lines per sq. cm. in air.

B—the magnetic induction, or no. of lines per sq. cm. in iron.

The curves shown for the seven kinds of iron and steel are quite representative of the varieties used in the construction of dynamos, motors, transformers, impedance or choke coils, etc. Individual specimens will show varieties in detail, and even various samples of the same sort of material will show slightly different features. All such material should be thoroughly tested before being used in any constructive work for the purpose indicated.

Mild cast steel, cheaper than soft annealed iron, has come into extensive use for the frames of dynamos and motors. It is allied to the low-carbon irons, in composition containing about 25% of carbon, and is readily cast and machined.

Mitis metal is sometimes used for frames of machines, is a kind of cast wrought iron, a variety rendered fluid by the addition of a small percentage of aluminium. It is more magnetizable than cast iron, and almost equal to the better grades of wrought iron.

Wrought iron, however desirable from its magnetic properties, is prohibited for field frames by the great expense attending its use.

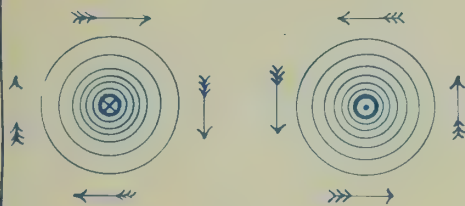
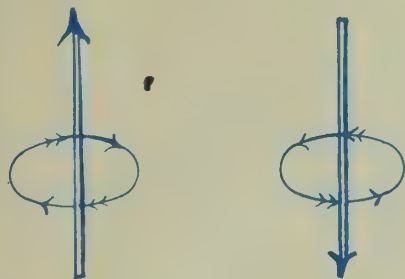
Sheet steel is used almost exclusively for the laminations required in the cores of armatures, transformers and choke coils; in the pole-pieces of dynamos and motors; and in the cores of induction motors, both for the stationary and the rotating parts.

Cast iron is variable with a decreased permeability in proportion to the amount of carbon present in the combined state.

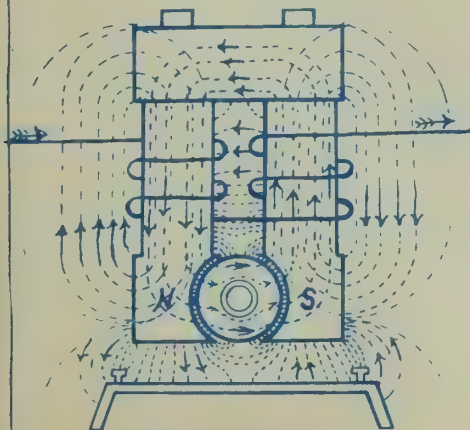
Hammering, rolling, chilling or any process tending to physically harden iron lessens its permeability. It may be restored again by raising to red heat and very slowly cooling, as in annealing.

Increasing temperature decreases the magnetic property, and at 600 degrees C. it begins to disappear.

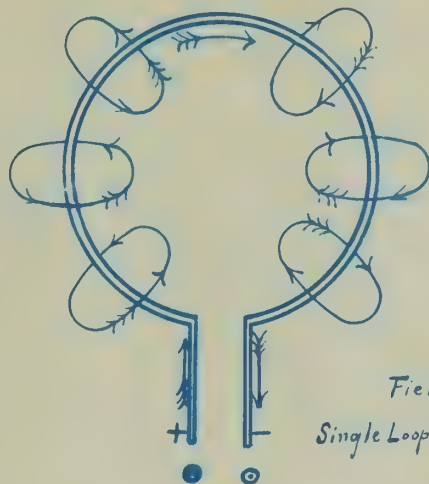




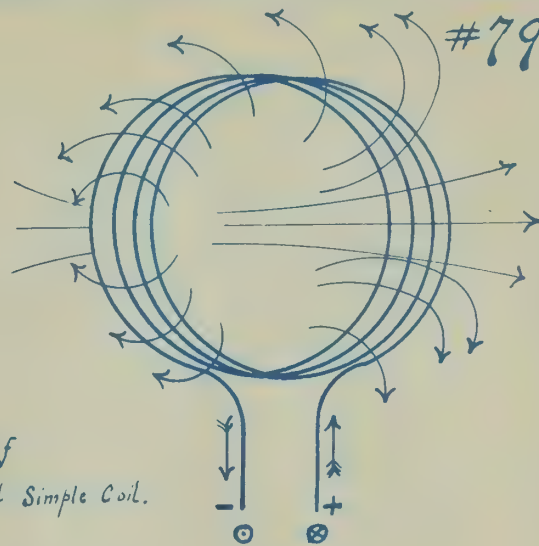
Field of Single Conductor.



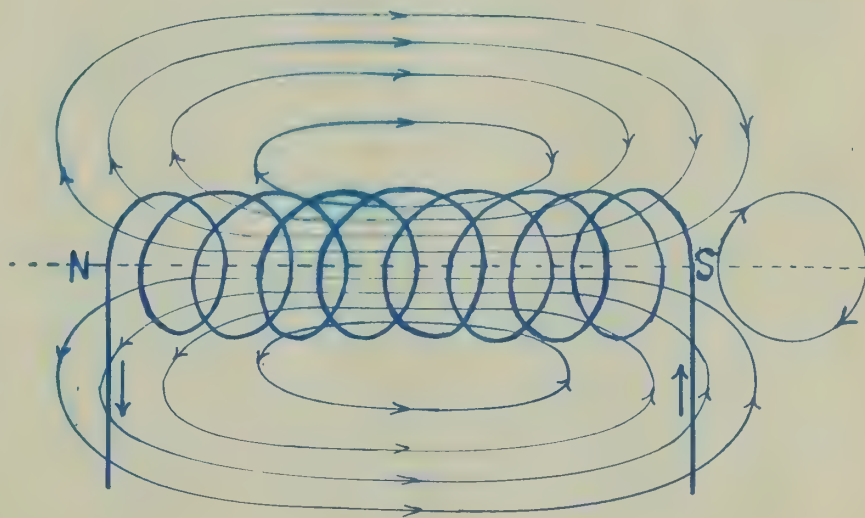
Field of Dynamo



*Field of
Single Loop and Simple Coil.*



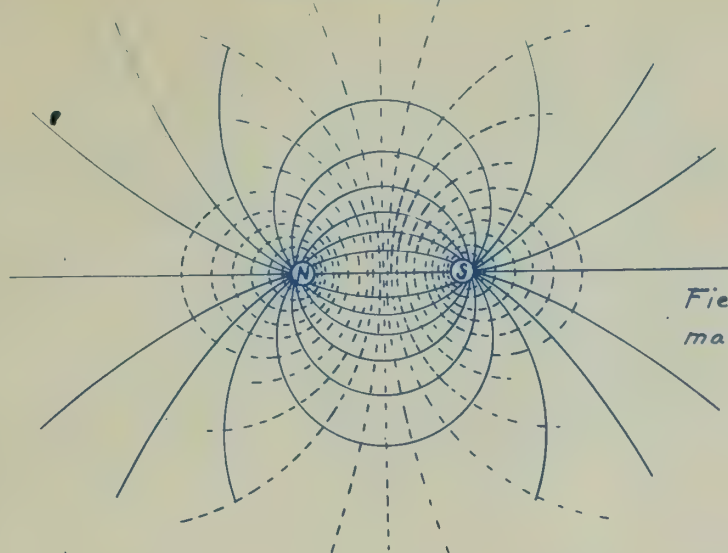
#79



Field of Solenoid.

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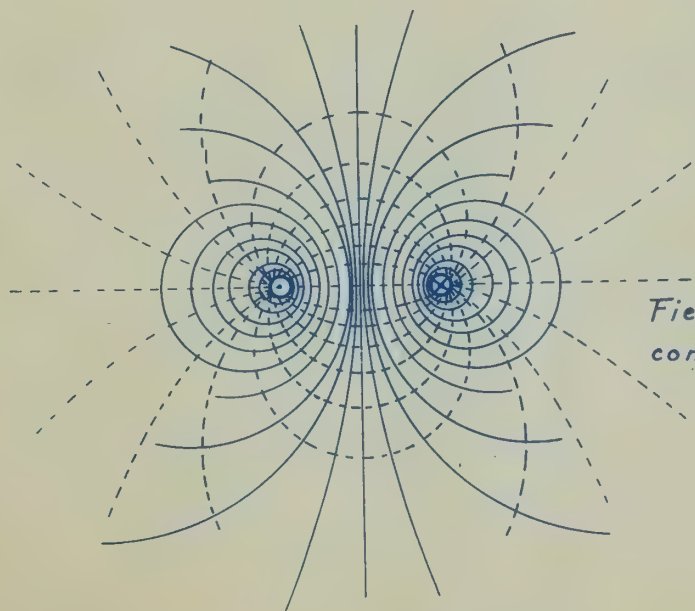
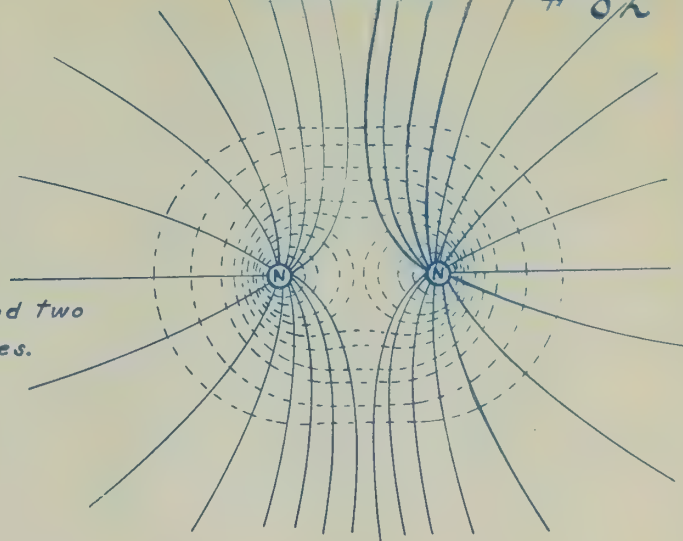
Dissimilar Poles.



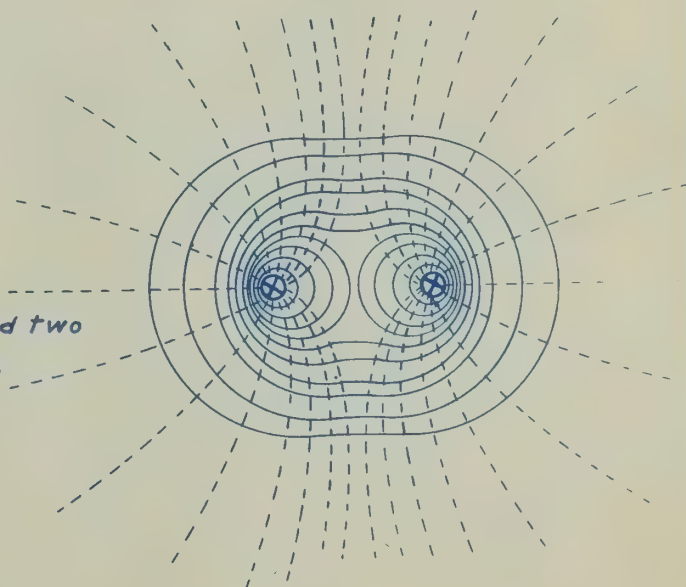
*Field around two
magnet poles.*

Similar Poles.

82



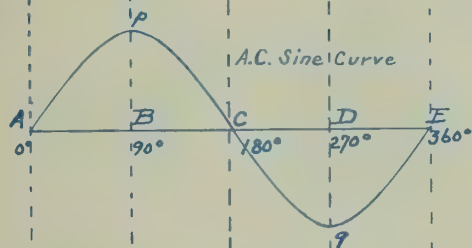
Currents in opposite directions.



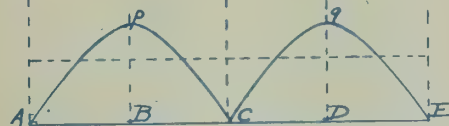
Currents in same direction.

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Elementary Type of single-phase generator.



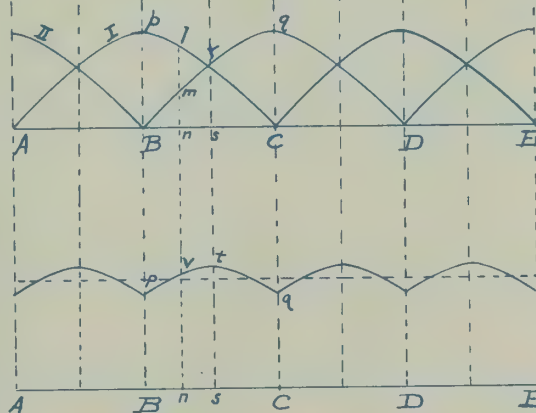
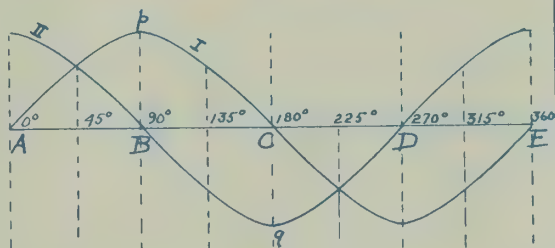
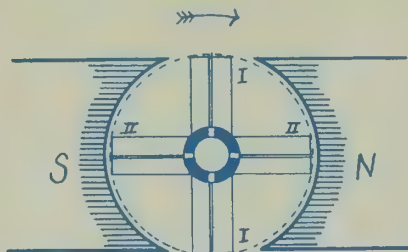
Curve of E.M.F., as generated.



Curve of E.M.F., as rectified by commutator.

Single-Coil Armature.

Elementary Type of two-phase generator.

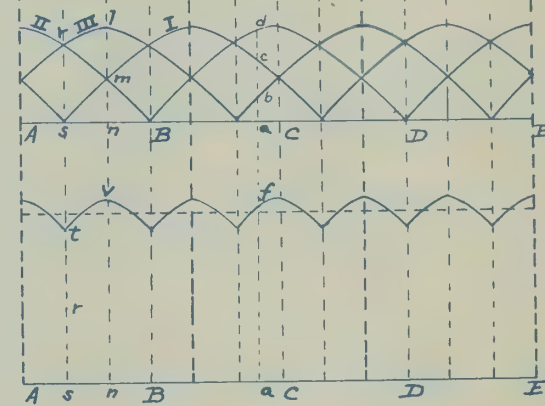
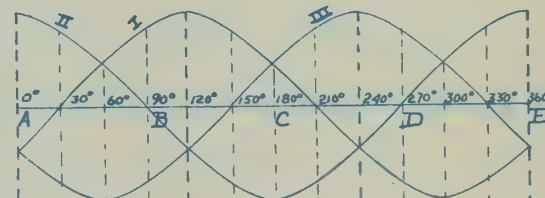
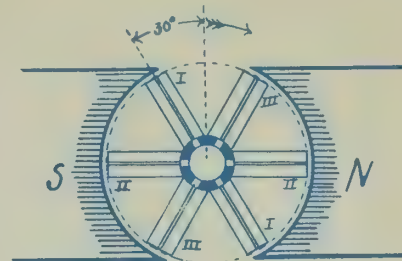


Curve of added values of E.M.F. $nv = nm + nl$; re.

Two-Coil Armature.

#103

Elementary Type of three-phase generator.



Curve of added values of E.M.F. $af = ab + ac + ad$; re.

Three-Coil Armature.

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A.D.C.G.F.

Curve of induced electromotive-force.

A.D.C.K.F.

Curve of squares of ordinates of A.P.D.T.C.

Arithmetic Mean or Average E.m.f. CV ,

$$= \gamma_{av} = \frac{2}{\pi} \gamma_{max} = 0.63663 \gamma_{max}.$$

Effective E.m.f. CR , $= \sqrt{\text{mean square}}$,

$$= \gamma_{rms} = \frac{1}{\sqrt{2}} \gamma_{max} = 0.70711 \gamma_{max}.$$

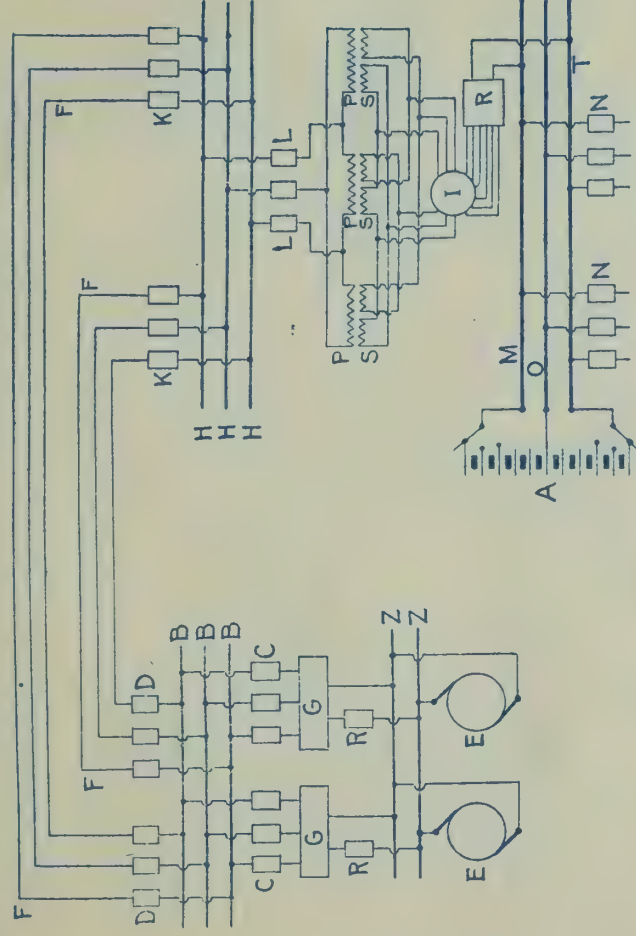


Action of the Commutator of Direct Current Machines.
A.D.C.G.F. Curve of Induced Electromotive-force.
A.D.C.K.F. Rectified Curve of Electromotive-force.
A.M.F. Integrated Curve of Potential.



Fig. 2

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Three-phase Transmission and Direct Current Distribution.

The generators *GG* are connected in parallel to the bus bars, *B*, *B*, *B*, through switches and oil circuit breakers, or fuses *CC*.

The field magnets of all the generators are supplied in parallel from a set of direct current exciters, *EE*, in the ordinary manner

From the main bus bars, feeders *FF* lead out through oil circuit breakers or fuses, *D*, and run to the sub-station or stations from which the energy is to be distributed. The drop on the feeders is either 5 or 10 per cent, giving 6300 or 6000 volts at the sub-station. These feeders are usually underground cables. After the feeders enter the sub-station, they again pass through fuses or oil circuit breakers, *KK*, and then to the high tension bus bars *HHH*, from which the primary circuits of the static transformers *S*, are supplied through oil circuit breakers, *LL*. In these transformers the energy is stepped down from 6300 or 6000 to about 165 volts, and is then fed into rotary converters, *R*, which change it into direct current at about 270 volts.

Regulation of the direct current voltage is effected by means of induction regulators *L*.

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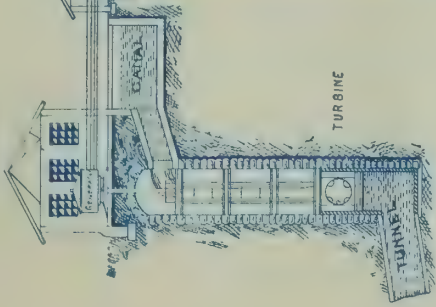
126

NIAGARA FALLS POWER CO.

11000 VOLTS-3 PHASE.

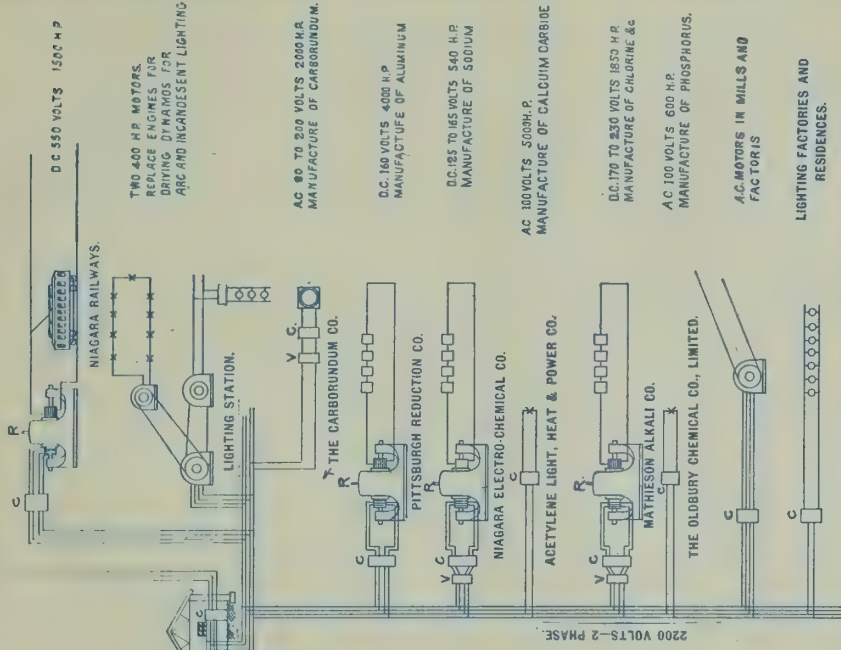
POWER HOUSE.

8-5500 H.P. A.C. GENERATOR



TURBINE

C-CONVERTER OR TRANSFORMER.
R-ROTARY FOR RECEIVING ALTERNATING AND DELIVERING DIRECT CURRENT.
V-REGULATOR FOR CHANGING VOLTAGE.
A. C.-ALTERNATING CURRENT.
D. C.-DIRECT CURRENT.



TONAWANDA-13 MILES FROM NIAGARA.

D.C. 550 VOLTS 1000 H.P.

NIAGARA-BUFFALO RAILWAY.

A.C. POWER DISTRIBUTION CIRCUITS
4400 VOLTS

BUFFALO-28 MILES FROM NIAGARA.

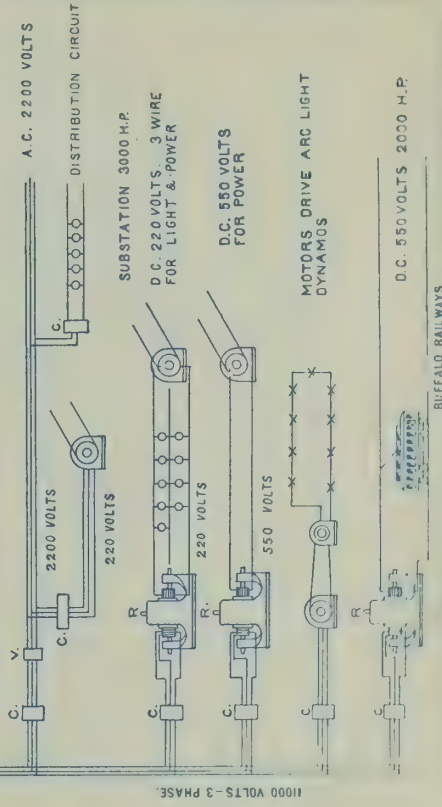
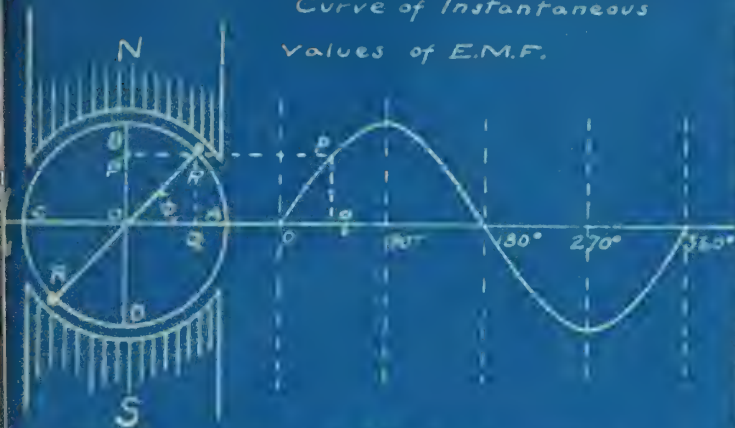


Diagram of Circuits from Niagara Plant, Showing Application of Power

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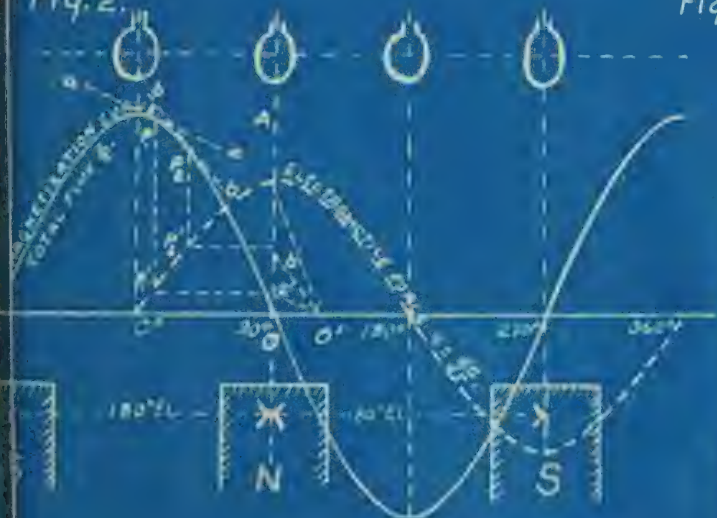
Fig. 1. Ideal Condition.

Curve of Instantaneous Values of E.M.F.



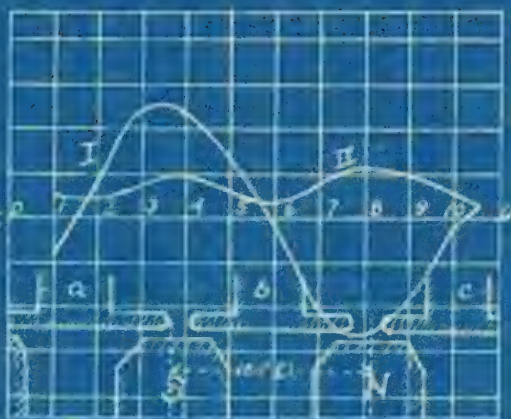
Generation of Ideal E.M.F. Sine Curve by Single Loop in Bipolar Field.

Fig. 2.



Relation of E.M.F. Curve to Curve of Distribution Magnetization, or Total Flux Curve.

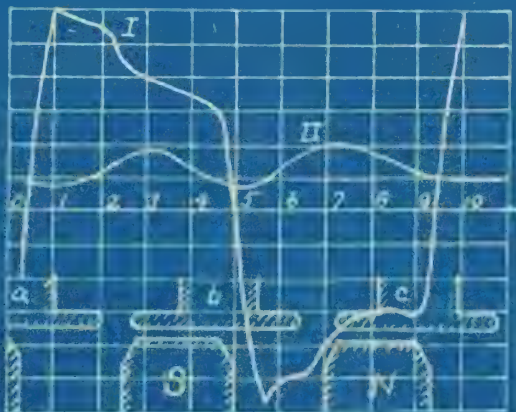
Fig. 3a. Real Condition.



I. Curve of instantaneous values of current in distorted field, machine short circuited.
II. Curve showing effect of field distortion on field current.

Fig. 4a.

Separately Excited 8-Pole Alternating Current Dynamo.



I. Curve of instantaneous values of current in distorted field machine full load.
II. Curve showing effect of field distortion on field current.



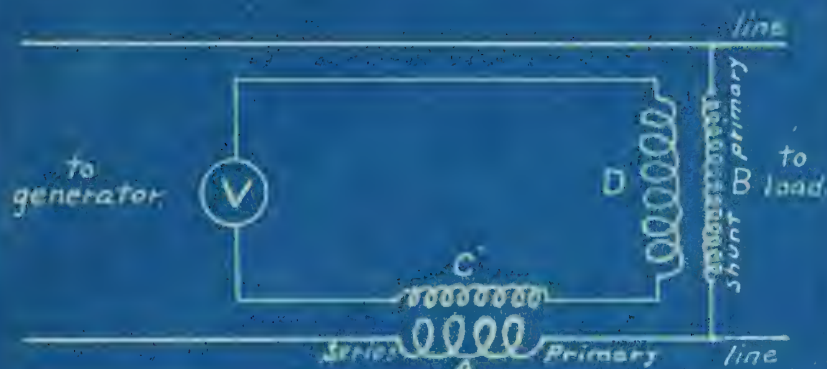
Relative location of field poles and armature at instant when current is zero.

Fig. 4b.



Relative location of field poles and armature teeth at instant when current is zero.

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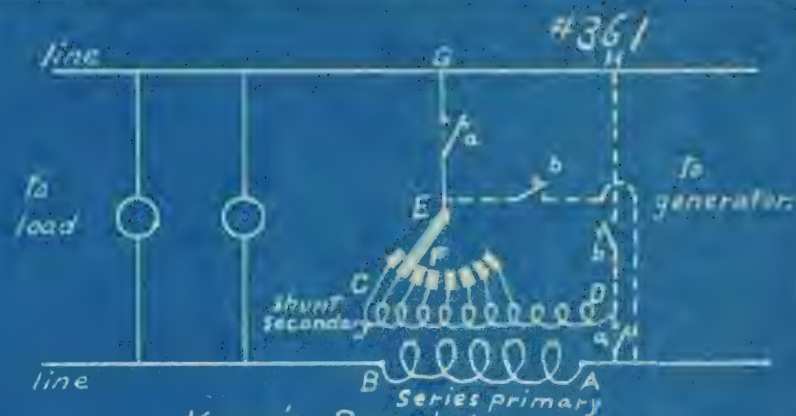
Kapp's Compensated Voltmeter.

Station Emf., E , measured by shunted transformer B; drop in the line, R_1 , indicated by secondary voltage of series transformer A. Voltmeter reading proportional to $(E - R_1)$ or the difference of potential at end of line.



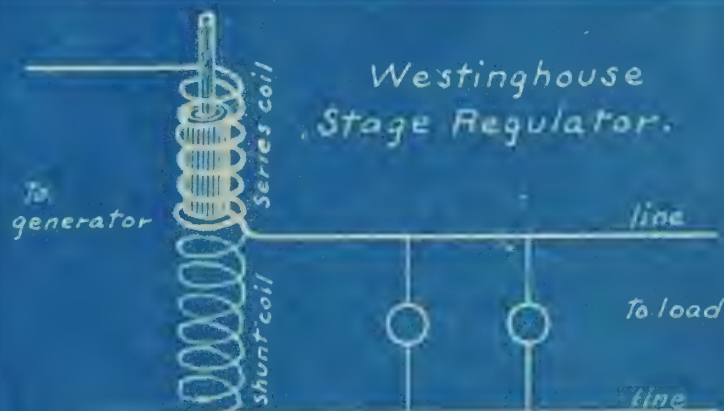
Stillwell Regulator.

To raise or lower Emf. of distributing circuit by adjusting number of secondary turns of the regulator.



Kapp's Regulator.

To maintain constant difference of potential at distant point, by adjusting number of turns, and direction of current in shunt coil of transformer.



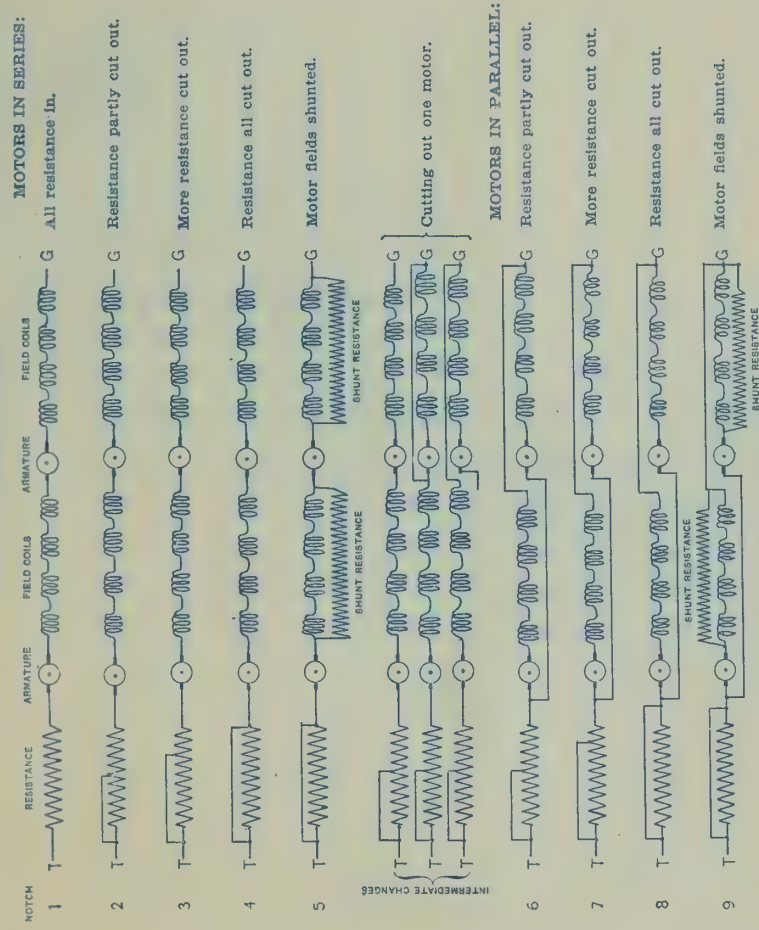
Westinghouse Stage Regulator.

- ① Core up; lamps dim; inductance of series coil a maximum and impedes current; lower coil acts as shunt to lamps with small impedance.
- ② Core down; lamps bright; inductance of shunt coil a maximum; impedance of series coil a minimum.

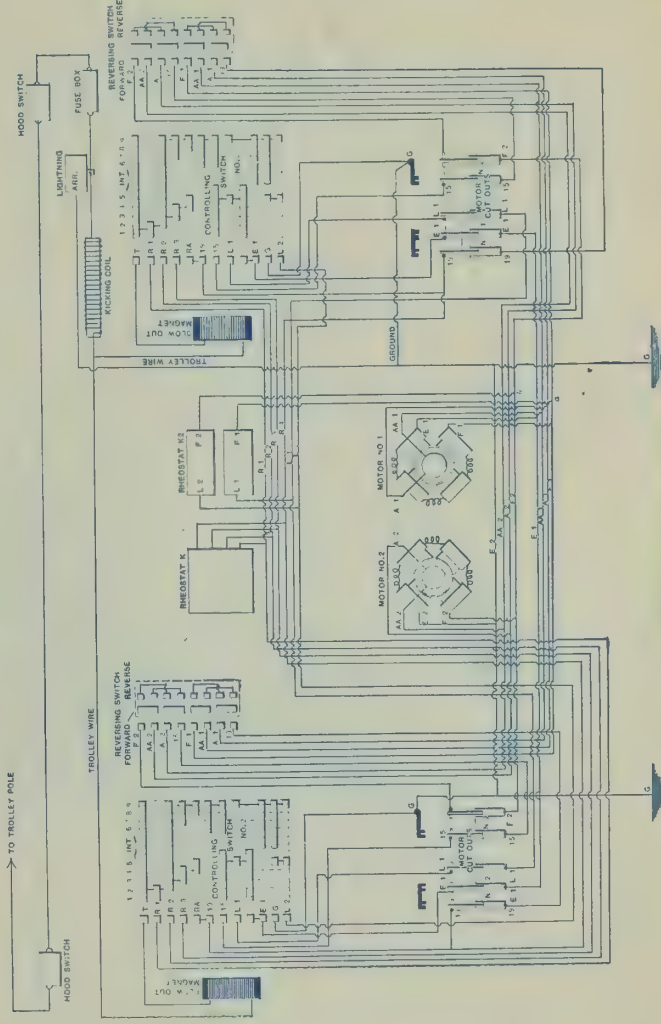
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DIAGRAMS OF ELECTRICAL CONNECTIONS.

K2 CAR CONTROLLER.

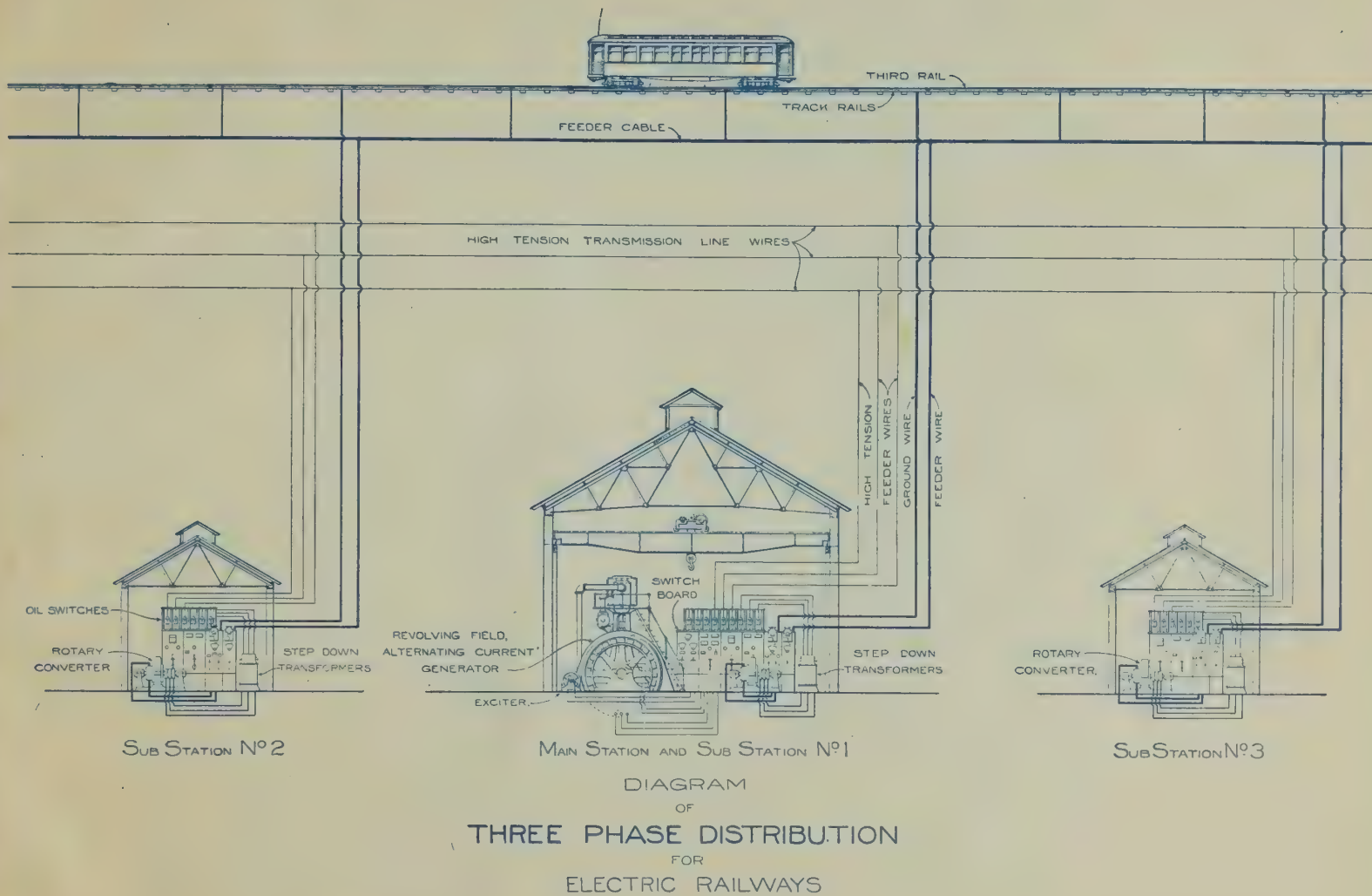


Electrical Relations at Each Notch of the Controller.



Wiring Diagram for K2 Controller.

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